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ABSTRACT

This paper discusses the results of a field study that attempted to answer questions related to science curriculum renewal in the province of Saskatchewan. The purposes of the field study were to obtain educators' reactions to proposals for change in the science curriculum, assess teachers' needs for science teaching, and determine the nature and extent of leadership and development required to improve the quality of school science in Saskatchewan. The sample population was selected from all levels of teachers and administrators in the province. Recommendations for the improvement of science education are included for: (1) science education goals; (2) a framework and organization for science education; (3) emphasis of science curriculum; (4) teaching of science; (5) evaluation of science learning; (6) science teacher support; (7) societal issues; (8) science teacher education; (9) common essential learnings; and (10) individual and group differences. Appended is "Dimensions of Scientific Literacy" from the framework for curriculum development (Saskatchewan) which identifies common factors in the goals of science education. This document includes discussions on the nature of science, key science concepts, processes of science, values that underlie science, science-technology-society-environment interrelationships and science-related interests and attitudes. (KR)

SASKATCHEWAN INSTRUCTIONAL DEVELOPMENT & RESEARCH UNIT

ED323109

SCIENCE FOR SASKATCHEWAN SCHOOLS:
Field Study Report

Researcher/Writer
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SIDRU Research Report No. 6
June 1987

SE051 569

Faculty of Education, University of Regina, Regina, Sask. S4S 0A2

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SCIENCE FOR SASKATCHEWAN SCHOOLS:

FIELD STUDY REPORT

Prepared for the
Saskatchewan Instructional Development
and Research Unit

With Funding from the
Saskatchewan Department of Education

by
E.P. Hart, Ph.D.
June 1987

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Research that is contracted to a researcher, who subsequently defines his or her time in terms of the project, and that is designed to attend to the urgency of a deadline and to a sense of public significance has been called entrepreneurial crisis research. I would characterize this science project in those terms. Given the time lines and deadlines for background research, framework development, and field research, the project could not have been completed without the hard work and dedication of Helen Morrison, who acted as research assistant during the field study phase of this project. Without her effort, the science field study documents would have been considerably less polished, and it is doubtful if the overall quality of the project could have been achieved.

I would also acknowledge the dedication and work of the following groups and individuals: the Science Curriculum Advisory Committee, Saskatchewan Education's Internal Science Project Team and regional curriculum coordinators, and the Saskatchewan Instructional Development and Research Unit (SIDRU) at the University of Regina. Many others deserve credit; their contributions were valued. High quality information provided by hundreds of teachers, consultants, and administrators throughout the province has resulted in clear direction for the improvement of science education in Saskatchewan schools. I sincerely hope that the efforts of all of these individuals and groups were not in vain.

Paul Hart
June, 1987

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INTRODUCTION

What do teachers say about the current state of science education? How do teachers respond to proposals for change in the science curriculum? What kind of leadership and development is required to improve the quality of science teaching? This paper reports the results of a field study that attempted to answer these and other questions related to science curriculum renewal in the province of Saskatchewan.

The science education field study is one component of a larger study of science education initiated by Saskatchewan Education in 1986. The purposes of this larger study were to develop a sound theoretical foundation on which to base future curriculum activity, to provide an organizational framework that translates what is known about theory into guidelines for effective practice, to reality test this framework in order to temper those guidelines to the Saskatchewan context, and to provide recommendations for curriculum renewal in science for Saskatchewan schools.

This large-scale reexamination of the science curriculum, in turn, was guided by a comprehensive review of the entire education system in the province of Saskatchewan. As a result of this process, the science education study and its field study component were delimited by a new set of goal statements defined as a set of common essential learnings within a core curriculum. Science, as one of the required subject areas within this core of learning experiences, must contribute to the development of these common essential learnings. Thus, curriculum development in science must include broader perspectives than traditionally has been the case.

Curriculum development in science also occurs within the context of the field of science education. It occurs at a time when science education is undergoing major reexamination of rationale, purposes, scope, and methods. Following a decade of intense activity in science curriculum development and implementation, the 1970s was characterized as a period of disillusionment in science and science teaching (Anderson, 1983). It was also a period of assessment when serious attempts were made to evaluate the effectiveness of the science curriculum innovations of the 1960s. In Canada, the first attempt to examine science education nationally was the Science Council of Canada's science education study (Orpwood, 1985). The first Canadian involvement in international comparison of student achievement in science was through the Second International Science Study (Connelly, Crocker & Kass, 1985) and has resulted in more information about science education in Canada.

The results of these and other studies of science and science teaching, internationally, have not been encouraging. Problems with student science achievement and attitude toward science and case study descriptions of classroom operation have

resulted in a general consensus among science educators that science in schools is in a state of crisis. More recent data from Canadian research confirm that many international trends describing the nature of the crisis apply to Canadian schools. Within this context of uncertainty in the field of science education, a study of science in Saskatchewan schools should demonstrate relationships between local concerns and an international dilemma.

Curriculum development cannot proceed in a vacuum. It occurs within educational, cultural, and social contexts. It involves reflection on past and present programs by processes of consultation, discussion, and debate among stakeholders. It should be the result of distilled wisdom of research and theory insofar as they can be applied to effective practice. Thus, proposals for renewal in science education demand consideration of these complex factors as a means of establishing a basis for curriculum change.

PURPOSES OF THE STUDY

The purposes of the field study were (1) to obtain educators' reactions to proposals for change in the science curriculum, (2) to assess teachers' needs for science teaching, and (3) to determine the nature and extent of leadership and development required to improve the quality of school science in Saskatchewan.

METHODS OF THE STUDY

Sample

The population from which the sample was selected consisted of all elementary (K-6) teachers, all K-12 administrators (including directors of education or their designates), and all intermediate (7-9) and secondary (10-12) teachers of science in Saskatchewan. The rationale for selection of this target population was that virtually all educational stakeholders in science teaching should have equal probability of being selected during sampling. All administrators and elementary teachers have a stake in science teaching because science is a required subject K-10 in Saskatchewan schools. Beyond the elementary school level, science tends to be taught by subject specialists so that many teachers at intermediate and secondary levels could not reasonably be expected to comment on science and science teaching.

The sample for this study consisted of teachers and administrators systematically selected from each of the eight provincial educational regions designated for administrative purposes by Saskatchewan Education. Within each educational

region are approximately ten school divisions. Regional representatives were selected from each school division to attend meetings within their regions according to the following criteria: males and females in proportion to teaching populations at all teaching levels; one teacher from each of K-6, 7-9, and 10-12 levels; one principal or vice-principal; and one administrator. The rationale for selection was based on the principle that the study should include a balance of opinion between males and females, specialists and nonspecialists, and teachers in the three teaching levels (elementary, middle years, and secondary). In addition, a number of representatives were designated from federal- and Indian band-controlled schools and from French designated schools in the province.

Saskatchewan is a vast and geographically diverse province with a rural character. It has two "larger" cities, relative to many smaller urban centers, and a myriad of towns, villages, and hamlets. In the south, the communities are agriculture based; in the vast northern forest, the settlements are associated with mining and forestry. Northern Saskatchewan and some urban centers have high native Indian populations. Pockets of long-standing French cultural activity also characterize the province. In order to be as sensitive as possible to the diversity that exists over this large geographic area, sample selection was conducted by the regional curriculum coordinators who represent Saskatchewan Education in each of the educational regions. These coordinators worked with directors of education in their regions to ensure that selection criteria were achieved within the administrative limitations of each school division in the province.

Instrument

Description

The instrument employed in the field study consisted of four booklets entitled Science for Saskatchewan Schools: Proposed Directions (Field Study, Parts A, B, C, and D). Part A, Background Summary, attempted to provide a theoretical foundation for the study. It was a brief summary of an extensive review of the literature and research in science education. The purpose of the literature review was to identify the current thought and research that could provide a solid foundation for meaningful curriculum development in science education. From this review, key issues were identified for their potential in providing direction for science curriculum renewal. These issues were summarized and highlighted in Part A under the following headings: philosophy of science education, goals of science education, instructional strategies, evaluation, controversial issues, relationship of science to other school subjects and common essential learnings, teacher education and postsecondary articulation, and individual and group needs.

The review was comprehensive and was intended to demonstrate the depth of perspective that governed the development of proposals for renewal of school

science in Saskatchewan. Part A was intended to provide teachers with a "window on the world" of science education in the form of a highly condensed synthesis of key issues. It identified similarities between Canadian studies and those of other countries with respect to recommendations designed to rectify existing problems in school science. In essence, this summary was assumed to provide a global context and a broad foundation for curriculum decision making, albeit in highly condensed format. All educators had access to the complete literature review through Saskatchewan Education.

Part B of the field study documentation, Framework for Curriculum Development, attempted to translate the results of the review of research and literature into a proposed framework for K-12 core science in Saskatchewan. It also represented a brief summary of a much more detailed development paper that was prepared for Saskatchewan Education and was available to teachers and administrators on request. The purpose of this framework was to demonstrate how a somewhat loose amalgam of guidelines from research and literature could be synthesized into an organizational plan for a science curriculum. An overview of this plan is provided as Table 1.

The remainder of Part B provided more detailed descriptions of various program elements, including a major section on the dimensions of scientific literacy, and sections on science program and program support characteristics at elementary, middle years, and secondary levels of education. The framework was intended to give teachers a concrete, comprehensive (in the sense of inclusion of all major program elements) overview of a proposed K-12 science program. It was assumed that by providing teachers with a curriculum perspective from which to consider specific proposals, a deeper more meaningful discussion of program characteristics and their interrelationships would ensue. In effect, Part B was an attempt to merge the existing theoretical base of science education with an operationalized curriculum organization model as a means of identifying critical issues requiring resolution during program development. The science education literature currently provides little guidance on this theory-practice interface, and this has been a serious gap in the foundational basis for science education.

Part C, Topics for Discussion, and the corresponding Part D, Teacher Response Booklet, represent an attempt to carry one step further the translation of theoretical guidelines into meaningful curriculum characteristics. They are intended to focus the attention of teachers on those issues that represent discrepancies between existing and proposed operationalized curricula in science. Part C contains recommendations, rationale, implications, and questions on the following eleven topics for discussion: goals of science education, science curriculum framework, science curriculum emphasis, science curriculum organization, science teaching, evaluation in science, support system for science teachers, science-related societal issues, teacher education, relationship of science education to common essential learnings, and providing for individual and group differences. It was assumed that, by initiating discussion on these topics, key problems in subsequent cur-

riculum development could be identified. In essence, the topics for discussion were intended to provide the practical context, including social and cultural perspectives, required for sensitive and meaningful program development.

Part D, Teacher Response Booklet, was designed to facilitate teacher response to the questions posed under each of the eleven topics for discussion in Part C. The first question in each topic for discussion asked for teacher reaction to the recommendation. Educators were reminded in the instructions to refer to Parts A and B for more detailed information. A variety of question types was used to elicit teacher response, ranging from multiple choice and rank order questions to open-ended questions. Many of the open-ended items requested participants to give reasons for their opinions. According to Aikenhead et al. (1987), these reasons tend to rely on conceptual knowledge, including misconceptions, which defines, in a cognitive sense, how a teacher views a topic for discussion. In this study, examples of cognition included understanding of "scientific literacy," consideration of "authentic" science, and the meaning and implications of a "science-technology-society-environment emphasis." Space was provided at the end of the response booklet for additional comments. Educators also had the option of submitting opinions and ideas through written briefs independent of the response booklet.

The Official Minorities Language Office (OMLO) of Saskatchewan Education provided French translations of Parts C and D of the instrument to participating teachers and administrators from French designated schools. These participants were given the choice of responding with the English or French versions.

The instrument was not intended to simply survey the current working conditions or expressed needs and wants of teachers of science. It was designed to provide teachers and administrators with a thoughtful and substantiated set of proposals for renewal of science education at the school level. The proposals were framed in the form of recommendations for change directed at Saskatchewan Education. The recommendations were subject to change based on collective reaction to their form and substance.

The following descriptions of the development procedure and regional meetings illustrate how the Saskatchewan science study attempted to blend the best features of the discrepancy model, employed for large-scale examination of science education in the United States, and the deliberative inquiry model, used for similar examination of science education in Canada.

Development Procedure

Development of the instrument occurred over a period of months so that validity and reliability could be closely examined. Part A was designed to provide the research and theoretical background as well as rationale; Part B was designed to provide the conceptual and organizational frameworks--the comprehensive K-12

Table 1 Summary of Framework for Science Curriculum Development

Program Elements	Elementary (K-5)	Middle Years (6-9)	Secondary (10-12)
Program Goals (Conceptual Basis for Program Development)	Scientific Literacy - objectives derived from dimensions of scientific literacy and including a balance of the following seven dimensions appropriate for each grade level • nature of science • key science concepts • processes of science • values that underlie science • STSE* interrelationships • science-related interests and attitudes • scientific and technical skills		
Program Emphases (Rationale for Program Development)	STSE emphasis overlying a Solid Foundation emphasis and a Structure of Science emphasis - implies attention to technological and environmental literacy - attempts to achieve a balance among major science education emphases Solid Foundation based on Structure of Science with STSE emphasis	Structure of Science for Solid Foundation using STSE emphasis	STSE emphasis based on Structure of Science and Solid Foundation
Program Design (Organizational Basis for Program Development)	Broad Fields with subject matter topics drawn from a variety of science areas (life, earth, physical) Curriculum materials from a variety of sources but curriculum guide ensures balance among all dimensions of scientific literacy Teachers with more extensive science background given flexibility to adapt with a general framework	Broad Fields with life, earth, and physical science balance within a framework of scientific literacy provided by curriculum guide Stronger STSE emphasis dominates so that subject matter is learned in a problem-issue-decision context	Two streams, both university acceptable A. STSE Science - focus on topics, issues, problems, information access, and information processing using science understandings applied to personal-societal concerns B. Disciplines Sciences - biology, chemistry, and physics but reoriented to STSE emphasis and designed to meet all objectives of scientific literacy
Teaching Methods and Materials	Curriculum guide provides Scientific Literacy Framework Guide either provides or recommends a wide variety of available materials with - proper format, illustrations, appearance, and readability	Similar to Elementary but with - more content application in line with STSE emphasis - careful selection of resource materials to avoid over reliance on one textbook - scientific literacy guidelines with a much broader	A. STSE Science - carefully selected modules - curriculum mapping to ensure basic concepts are covered - beginning and advanced level courses (10 and 11)

	• teacher background • activity organization • integration ideas • scope and sequence • evaluation devices • teaching aids	approach to science than content presentation • scientific literacy assessment to ensure curriculum is followed	B. Disciplines Sciences • reoriented to comply with scientific literacy and STSE emphasis • scientific literacy used as a basis for secondary science assessment
Teaching Roles and Relationships	Active participation by teachers and students in hands-on activities Open-ended activities stressing cooperative problem solving but accounting for ability levels and need for autonomy and independence Multisensory activities Reading opportunities as well as written and oral communication Increasing responsibility Maintaining curiosity	Cooperative problem solving by teacher and students using activities, information gathering, and decision-making skills (team approach to learning) Concrete activities that foster independence, self-concept, and maturity Importance of teacher as role model of an avid, curious investigator and problem solver using values underlying the nature of science and processes to logically reach conclusions	Teacher has key role as organizer for problem identification and information access, interpretation, and application to problem resolution Students responsible for pursuing subject matter, then teacher helps students understand meaning and application Teacher models scientific problem solving
Learning Environments	School and classroom as a base for community and nature study using schoolyards, parks and neighborhoods	As in Elementary but with more reliance on community resources and applications of science and technology subject matter	Wide variety of activities and information gathering within local community and natural settings that examine wider systems
Operating Conditions	Administrative understanding and cooperation		
			Use of communications networking
Research and Development	Teacher as researcher who uses process of science to assess the results of alternative teaching methods in cooperation with science educators		

*STSE — science-technology-society-environment

overview--on which the set of recommendations proposed in Part C would be grounded. It was assumed that the inclusion of Parts A and B in the field study documentation package would increase the probability of gathering informed educator opinion.

The format for Parts C and D was, in part, determined by Saskatchewan Education. Their earlier study of core curriculum used a format that was adopted as a model for the science education field study. It seemed logical to use a format that had proven to be successful in eliciting educator and public response to core curriculum proposals as it would be familiar to participants in the field study. It was assumed that recent experience with this particular format would permit participants to devote more of their energy to matters of substance.

The development of Part C began with the phrasing of recommendations as logical curriculum implications of proposals in Part B which, in turn, arose logically from the science education research and literature. Several committees participated in the wording of recommendations, rationale, and implications and in question development. The instrument was scrutinized by personnel in the Curriculum Development Division of Saskatchewan Education; by an internal project team of the department; and by the Science Curriculum Advisory Committee, an external committee to Saskatchewan Education consisting of teachers, school board members, administrators, and university faculty members. Instrument questions were added, modified, and deleted until questions could be found for each discussion topic that satisfied the following criteria: (1) required responses for curriculum development decisions; (2) elicited true, accurate, or reliable teacher responses; (3) were clear and understandable to educators; and (4) accurately reflected the scope and depth of educator opinion. A preliminary instrument was pilot tested with a group of teachers, members of elementary-intermediate and secondary science curriculum committees in one provincial school jurisdiction. After all individuals and groups had approved the instrument for field use, the Curriculum Development Division of Saskatchewan Education required the approval of regional curriculum coordinators before the instrument was permitted to be used with teachers and administrators throughout Saskatchewan.

The final edition of the instrument consisted of the four booklets described above and required educator response to questions posed under the eleven topics for discussion shown in Table 2.

Regional Meetings

Subjects for this study, referred to as regional representatives or participants, each attended a day-long meeting in their region of the province. The number of meetings held in each region varied from one to three. The purpose of the regional meetings was to formally present the proposals for curriculum renewal in science,

to allow participants an opportunity to discuss and clarify their perceptions of the proposals, to facilitate discussions among teacher groups (elementary, middle years, and secondary) and administrators, and to provide a forum where response booklets could be completed by participants with access to the researchers, colleagues at all educational levels, Saskatchewan Education personnel, and administrators.

A complete set of instrument booklets was distributed to participants one to two weeks prior to their scheduled regional meeting. Although a few participants had formulated responses to some or all of the discussion questions prior to attending their meeting, most of them completed the response booklet after the formal presentation at the meeting. The completed response booklets were then collected from the participating regional representatives at the end of each meeting.

It should be emphasized that the regional meetings were designed to identify discrepancies between the proposal and actual operating conditions through a deliberative process. The purpose of deliberation is to ensure that the relevant facts and values implicit in proposed alternatives can be weighed against the characteristics of the situation for which decisions are to be made (see Orpwood, 1983). In this process the political realities of the school curriculum can be included in final determination of policy direction. The essence of the process is participatory decision making where teachers, as professionals, are assumed capable of engaging in direction setting.

Table 2

Topics for Discussion in Science Education Field Study

Topic	1	Goals of Science Education
Topic	2	Science Curriculum Framework
Topic	3	Science Curriculum Emphasis
Topic	4	Science Curriculum Organization Elementary Science (K-5) Middle Years Science (6-9) Secondary Science (10-12)
Topic	5	Science Teaching
Topic	6	Evaluation in Science
Topic	7	Support System for Science Teachers
Topic	8	Science-Related Societal Issues
Topic	9	Teacher Education
Topic	10	Relationship of Science Education to Common Essential Learnings
Topic	11	Providing for Individual and Group Differences

Analysis

A total of 337 participants attended regional meetings and submitted response booklets. This sample, stratified for regional representation and within regions for educational level (which included appropriate gender and specialist proportions), was assumed to adequately represent a saturation of the views of Saskatchewan educators concerning their reactions to proposals for renewal in science education and their perceived needs in order to deliver a quality K-12 science program to Saskatchewan students. Question results were subjected to appropriate statistical and qualitative analyses. Multiple choice and rank order question responses were numerically coded by research assistants and statistically analyzed using the Statistical Package for Social Sciences (SPSS^{x}). Responses to open-ended questions, open-ended portions of multiple choice questions, and additional comments made by participants were recorded and duplicate answers or statements tallied so that a summary of response types was determined for each question. Research assistants recorded and tallied the answers to the open-ended portions of multiple choice questions during the numerical coding process. Members of the Science Curriculum Advisory Committee recorded and tallied the answers to the open-ended questions and the additional comments in a later workshop session.

Although not included for purposes of analysis in this report, responses from a much wider group of subjects were considered in the decisions surrounding policy direction setting for science education in Saskatchewan. Several instrument packages were distributed to each of the 1,150 schools in the province so that every teacher, administrator, and teacher group had the opportunity to react to the recommendations using the response booklets provided or by generating written briefs.

RESULTS

Descriptive Data

In general, the results of this report detail provincial data. Table 3 displays the results of the attempt to select a representative sample of educators stratified by region.

An objective of the sampling procedure used in this study was to determine if there was variation among certain subgroups. Tables 4, 5, 6, 7, and 8 illustrate the results of sampling by teacher level, school type, school location, involvement in administrative duties, and teaching experience.

Saskatchewan science teaching has not been intensively studied prior to the field study. This study represented the first attempt, at a provincial level, to give serious consideration to the views of teachers prior to curriculum development. The researchers worked cooperatively with Saskatchewan Education personnel to obtain administrator and teacher cooperation. Because the regional curriculum coordinators, who arranged with the directors of education to have teachers and administrators participate, were unable to have representatives from all school divisions, sampling error is a possibility. However, the sample size and the absence of regional variation in response categories appears to indicate that these errors

Table 3

Breakdown of Educators Sampled by Region[a]

Region	Number of Participants	Percentage
1. Southeast	38	11.3
2. Southwest	53	15.7
3. East Central	30	8.9
4. West Central	62	18.4
5. Northeast	55	16.3
6. Northwest	33	9.8
7. Regina	33	9.8
8. Northern Education Unit	33	9.8
Total	337	100.0

[a] Educational regions designated by Saskatchewan Education and in existence during the field study period (October, 1986 to April, 1987).

Table 4

Breakdown of Educators Sampled by Teacher Level

Level	Number of Participants	Percentage
Elementary	107	31.8
Elem.-Intermediate	21	6.2
Intermediate	40	11.9
Interm.-Secondary	63	18.7
Secondary	52	15.4
Elem.-Interm.-Sec.	7	2.1
No Level Indicated[a]	2	0.6
None of Above[a]	27	8.0
Missing[a]	18	5.3
Total	337	100.0

[a] Teachers were not required to answer all questions.

Table 5

Breakdown of Educators Sampled by Type of School

School Type	Number of Participants	Percentage
K-12	92	27.3
K-8	30	8.9
K-6	55	16.3
7-9	13	3.9
7-12	28	8.3
9-12	12	3.6
10-12	15	4.5
Other	52	15.4
Missing	40	11.9
Total	337	100.0

Table 6

Breakdown of Educators Sampled by School Location

School Location	Number of Participants	Percentage
City[a]	82	24.3
Town-Village	209	62.0
Other	5	1.5
Missing	41	12.2
Total	337	100.0

[a] Saskatchewan is a rural province. Only two cities have populations exceeding 150,000. City schools include those in the two large cities and those in the several smaller cities in the province (populations over 5,000 and incorporated).

Table 7

Breakdown of Educators Sampled by Administrative Involvement

Administrative Involvement	Number of Participants	Percentage
Yes	90	26.7
No	231	68.5
Other[a]	11	3.3
Missing	5	1.5
Total	337	100.0

[a] Primarily consultants.

Table 8

Breakdown of Educators Sampled by Years of Teaching Experience

Teaching Experience (Years)	Number of Participants	Percentage
0 - 5	48	14.2
6 - 10	60	17.8
11 - 20	142	42.1
>21	72	21.4
Missing	15	4.5
Total	337	100.0

were minimized. This, together with a random sampling from approximately 800 additional response booklets sent in by teachers and teacher groups not participating in the regional meetings and showing no marked response differences from the participant sample, indicates a relatively high degree of reliability in the provincial estimates.

An important component of the database was the descriptions of the science- related background of participants. Tables 9, 10, and 11 display participant science teaching levels, specific courses taught at intermediate and secondary levels, and science and science education background.

Nearly two-thirds (63.5%) of the participants were experienced educators (had taught more than 10 years). Over one-half (53.1%) of the educators sampled had

Table 9

Breakdown of Educators Sampled by Science Teaching Level

Teaching Level	Number of Participants	Percentage
K-3	31	9.2
4-6	70	20.8
K-6	11	3.3
7-9	40	11.9
4-9	11	3.3
K-9	8	2.4
10-12	41	12.2
7-12	72	21.4
4-12	6	1.8
None of Above	21	6.2
Missing	26	7.7
Total	337	100.0

Table 10

Breakdown of Intermediate and/or Secondary Level Educators Sampled by Science Courses Taught

Science Courses Taught	Number of Participants	Percentage
Intermediate Level[a]		
Life Science (7)	87	63.5
Earth Science (8)	78	56.9
Physical Science (9)	81	59.1
Secondary Level[b]		
General Science (10)	78	65.5
Physics (11-12)	45	37.8
Biology (11-12)	72	60.5
Chemistry (11-12)	75	63.0
Geology	3	2.5
Agriculture	5	4.2

[a] Total number of teacher participants who reported teaching science courses at the intermediate level was 137.
[b] Total number of teacher participants who reported teaching science courses at the secondary level was 119.

Table 11

Breakdown of Educators Sampled by Science and Science Education Background

Background	Number of Participants	Percentage
High School Science Only	17	5.0
Minimal Background[a]	162	48.1
Several Science Classes	55	16.3
B.Sc. or B.A. in Science	86	25.5
Masters Level (M.Sc. or M.Ed.)	10	3.0
Missing	7	2.1
Total	337	100.0

[a] Participants with only one or two science/science education classes. This group includes those participants with a B.Ed. with a major in an area other than science.

minimal exposure (fewer than two courses) to science in their educational background. There appears to have been a reasonable balance of educators in the sample with respect to specialist science and nonscience teachers, level of teaching and science courses taught, school type and location, and regional representation. Secondary participants, excepting administrators, tended to be science teachers or science specialists. Elementary and intermediate teachers (who did not teach intermediate levels as an adjunct to secondary science) tended to be generalists who had less exposure to science or science education classes and who considered themselves teachers of science, but only as a part of their total teaching responsibilities. Of the 337 participants, 15 (4.5%) were affiliated with French designated schools and responded with French or English versions of Parts C and D, 7 (2.1%) indicated affiliation with federal- or Indian band-controlled schools, and 315 (93.5%) were affiliated with the regular provincial school system.

Reaction to Proposed Recommendations

This study attempted to combine the most meaningful and useful components of the deliberative inquiry model employed by the Science Council of Canada's science education study (Orpwood, 1985) and the discrepancy model used by Project Synthesis (Harms & Yager, 1981). The topics for discussion in Part C focussed educator attention on eleven recommendations proposed for the renewal of science education in Saskatchewan. Educators were asked to comment on discrepancies between actual and proposed states of science in schools. However, unlike the pure discrepancy model used in Project Synthesis, the raw material for synthesis of results was the feedback from teachers based on deliberative sessions,

not the analysis of social indicators and expert reports in the literature. Thus, during the course of this study, as in the Science Council of Canada's study, political commitment was being examined as rational conclusions were being generated. Awareness of this rational-political duality of curriculum policy making (Orpwood, 1985) was central to the conduct of this study as can be seen in the high degree of importance attached later in this paper to analysis of written responses to open-ended questions.

Participants in regional meetings were asked to respond, on a 5-point Likert scale ranging from strongly agree to strongly disagree with undecided as the center point, to the recommendations set forth in each of the eleven topics for discussion. After the background presentation at each meeting, participants formed discussion groups to complete response booklets. Although the primary task for each individual participant was completion of responses to his or her satisfaction, discussion was encouraged for clarifying views and perceptions or testing ideas. Table 12 displays the results of educator reaction to each of the eleven major recommendations proposed in the study.

In 1984, the Science Council of Canada concluded a national study of science education by making 47 major recommendations for what was described as urgently needed renewal in Canadian science education. Through synthesis of most of these recommendations in the context of studies of science education from other countries, this study attempted to initiate further deliberation in one province. The impression conveyed by examination of Table 12 is that teachers agree that change is required and that the direction of that change should be toward what was proposed in the science framework (Part B) and topics for discussion (Part C). However, mindful of cautions that must be considered when interpreting such data (Aikenhead et al., 1987), more weight was given to responses than is typical in studies of this kind.

What follows is an attempt to blend the objective and subjective interpretation of educator responses to the eleven major recommendation categories on a topic by topic basis. Note that participants were not asked to react to recommendations "point blank." Written background literature and framework summaries were made available to all participants prior to the regional meetings and a formal presentation (1-2 hours) of the curriculum proposals was given at each meeting. This was followed by small group formation for purposes of discussing and responding to questions under each topic.

Table 12

Reaction of Educators Sampled to Major Recommendations Proposed for Science Education

Topic	Recommendation[a]	Reaction (Percentage)[b] Agree	Undecided	Disagree[c]
1	Goals of Science Education (participants responding = 334) The major goal of science education in K-12 should be the development of scientific literacy in all of its seven dimensions.	98.2	1.2	0.3[d]
2	Science Curriculum Framework (participants responding = 335) A science curriculum framework for K-12 should be developed to organize the continuity and flow of core science learning experiences.	97.3	2.7	--
3	Science Curriculum Emphasis (participants responding = 323) Science curricula at all levels of K-12 education should include a science-technology-society-environment emphasis.	87.9	11.1	0.6

Topic	Recommendation	Reaction (Percentage) Agree	Undecided	Disagree
4	Science Curriculum Organization			
	Elementary Science (K-5) (participants responding = 207) Science learning experiences should be provided for the minimum time prescribed by Saskatchewan Education. The curriculum should provide for development in all dimensions of scientific literacy, reinforce the elementary program, and be activity oriented.	98.1	1.4	0.5
	Middle Years Science (6-9) (participants responding = 172) Science learning experiences should contribute to development in all dimensions of scientific literacy. Science should be acitivity oriented, personally/socially relevant, and emphasize process skills.	95.3	3.5	1.2
	Secondary Science (10-12) (participants responding = 166) In addition to grade 10 science, two years of secondary science should be required. Discipline courses should be modified to satisfy all dimensions of scientific literacy. A second route should consist of two science-technology-society-environment courses. Both routes, or a combination, should be acceptable for university entrance.	63.3	22.3	13.2

Topic	Recommendation	Reaction (Percentage) Agree	Undecided	Disagree
5	Science Teaching (participants responding = 329) Science teachers should use a variety of teaching strategies appropriate for the material and for the needs, capabilities, and interests of students.	97.6	1.8	0.3
6	Evaluation in Science (participants responding = 330) Student evaluation should measure degree of scientific literacy. Teacher effectiveness and science programs should also undergo ongoing evaluation.	87.6	10.9	1.5
7	Support System for Science Teachers (participants responding = 333) Teachers should receive support from curriculum leaders at all levels in the form of materials, equipment and supplies, staff development experiences, and other teaching/learning aids.	99.4	0.3	--
8	Science-Related Societal Issues (participants responding = 332) The science curriculum should provide students with opportunities to discuss science- and technology-related societal and environmental issues at appropriate levels.	93.7	5.7	0.3

Topic	Recommendation	Reaction (Percentage) Agree	Undecided	Disagree
9	Teacher Education (participants responding = 323) Preservice teacher education should include university training in both physical and life sciences and should be consistent with the goals of science education. Mechanisms should be established to reward teachers who maintain a high level of professional competence. Inservice and workshops should be provided for science teachers.	85.1	10.5	4.3
10	Relationship of Science Education to Common Essential Learnings (participants responding = 321) Curriculum development should include detailed articulation between the goals of science education (dimensions of scientific literacy) and Saskatchewan's goals of education (common essential learnings).	91.0	7.8	0.9
11	Providing for Individual and Group Differences (participants responding = 324) Science curricula should make detailed provision for the special needs of all students. If possible, these provisions should be handled within the mainstream of science education.	87.3	9.3	3.4

[a] The recommendations are briefly stated here. Complete wording of each recommendation appears in the text following this table.

[b] For each topic, the percentage is based on the number of participants that answered the question. A response was disregarded when more than one answer was selected by the participant.

[c] The percentage of participants recorded as agreeing includes those who selected "strongly agree" or "agree" as their response. The percentage of participants recorded as disagreeing includes those who selected "disagree" or "strongly disagree" as their response.

[d] Percentages for each topic total less than 100% in several cases due to an inappropriate responses category (i.e., participant checked more than one response to the question) that was not included in the table.

Goals of Science Education (Topic One)

Recommendation: **The major goal of science education in K-12 should be the development of scientific literacy. The scientifically literate person**

- **-understands the nature of science and scientific knowledge;**
- **-understands and accurately applies appropriate science concepts, principles, laws, and theories in interacting with society and the environment;**
- **-uses processes of science in solving problems, making decisions, and furthering understanding of society and the environment;**
- **-interacts with the various aspects of society and the environment in a way that is consistent with the values that underlie science;**
- **-understands and appreciates the joint enterprise of science and technology and the interrelationships of these with each other and with other aspects of society and the environment;**
- **-has developed a richer, more satisfying, and more exciting view of society and the environment as a result of science education and continues to extend this education throughout life; and**
- **-has developed numerous manipulative skills associated with science and technology.**

There appears to be almost unanimous agreement with this recommendation (see Table 12). Of the 334 participants who reacted to this recommendation, 98.2% agreed. Examination of responses to other questions under this topic provided a clearer understanding of the viewpoints of educators on the goals of science education. For example, similar numbers of educators indicated that developing science concepts (69.4%), developing processes of science (67.0%), and developing positive attitudes toward science (69.4%) were important goals of their current science teaching. Other common goals in science teaching were given as follows: developing the relevancy of scientific knowledge; developing science-technology-society-environment relationships, and preparing students for subsequent grades. Less frequent current science goals included development of manipulative skills, development of self confidence, development of concern for future society, hands-on science, teacher role models, and developing excitement about science.

Educators also indicated that they would have more difficulty teaching toward certain dimension goals of scientific literacy. Developing science-related interests and attitudes (56.6%), developing scientific values (52.8%), developing understanding and appreciation of science-technology-society-environment interrelationships (44.7%), and developing scientific problem solving and decision

making process skills (31.9%) were perceived as more difficult to teach toward than developing understanding of the nature of science (13.1%), developing understanding of key science concepts and principles and their application (15.6%), and developing scientific and technical skills (18.4%). Reasons given for this anticipated difficulty included lack of familiarity with dimensions of scientific literacy (44.6%), with teaching techniques (47.8%), and with evaluation devices (43.6%). Additional reasons given for difficulty in teaching toward certain scientific literacy goals were lack of time, including teacher preparation time; lack of teacher confidence; and lack of student interest and ability to deal with difficult material.

Participants suggested the following ways of overcoming these difficulties: staff development or inservice (82.0%), curriculum materials (76.3%), and laboratory equipment and materials (42.9%). They added that increased teacher awareness of new methods and materials, increased teacher information access capabilities, and increased teacher preparation time would also help. Participants indicated that science consultants (69.7%), other teachers (53.2%), Saskatchewan Education personnel (52.6%), and others such as university specialists, administrators, and curriculum developers should also be responsible for helping teachers overcome these difficulties.

In general, teachers appear to favor a movement toward the multidimensional concept of scientific literacy as a worthwhile goal for science teaching as long as an adequate support system can be established to overcome some rather obvious difficulties necessitated by the transition.

In the regional breakdown of responses to the first recommendation, variation was minimal. Four regions indicated 100% agreement (Regions 1, 2, 4, and 7). Comparison of responses according to science teaching level also showed uniformity, and there were no distinct rural/urban differences in response to this recommendation.

Science Curriculum Framework (Topic Two)

Recommendation: **A science curriculum framework for K-12 should be developed to organize the continuity and flow of core science learning experiences. The framework will be used by curriculum developers and writers as they design science programs and by teachers as an aid to achieving a balance among all the dimensions of scientific literacy in their teaching. It can also be used by teachers and teacher committees as a general guide to planning and decision making within the adaptive portions of the science curriculum.**

Of the 335 educators who responded, 97.3% agreed with this recommendation. It appears that Saskatchewan teachers and administrators like the idea of a K-12 science framework. Do responses to additional questions and written responses support this perception? Apparently yes, but teachers have legitimate concerns about some of the elements of the framework, primarily teaching methods and materials (64.5%) and program design (44.6%). Written responses indicated that time, funds, inservice, and clarity of expectations in curriculum materials were major concerns that must be considered when any kind of change in program is contemplated. Other issues raised in written responses included the following: the need for balance, relevancy, and flexibility in the design of curriculum materials; motivation, cooperation, and facilitation in the development of teaching methods; and administrative and community support in implementation of new programs.

It was felt by 78.3% of those who responded, that there were no reasons why one science curriculum framework would not be able to meet the needs of all students and student groups in Saskatchewan. Although 21.7% responded negatively to this question, no reasons were given for the negative answer. Perhaps the negative wording of the question resulted in participants misunderstanding the question.

In the regional, science teaching level, and rural/urban breakdowns of responses to the second recommendation, there were no distinct differences. Three regions (Regions 3, 4, and 8) indicated 100% agreement. As well, urban teachers in Saskatchewan indicated 100% agreement with this recommendation.

Science Curriculum Emphasis (Topic Three)

Recommendation: **Science curricula at all levels of K-12 education should include a science-technology-society-environment emphasis.**

Of the 323 educators who chose to react to this recommendation, 87.9% were in agreement. It is important to note that, of the remainder, 11.1% were undecided. This larger undecided number of participants, relative to the first two recommendations, was expected. Without benefit of concrete examples of curriculum materials that include this emphasis, teacher uncertainty should be anticipated.

Participants indicated that the main emphases of their present science programs include the following: learning science skills as a means of problem solving (57.1%), preparing students for the next level of science study (54.9%), applying the principles of science to everyday situations (54.9%), and learning the correct explanation for science-related phenomena (44.6%). Less often mentioned were learning about the nature of each of the disciplines of science (37.5%), learning how science knowledge and technical information influence society and environment (34.9%), and examining growth and change in scientific ideas through time (27.4%).

It was encouraging that the uncertainties about the addition of a new curriculum emphasis were expressed positively. Traditionally, Saskatchewan teachers have displayed a cooperative spirit in the face of change if they believe that the underlying reasons are well grounded. Although a high degree of agreement with this recommendation was demonstrated, many written qualifiers indicated that educators were concerned about covering existing content, preparation of students for the next level of science, evaluation of students, availability of appropriate teaching materials, erosion of science content, abstractness of concepts, and difficulty in dealing with controversial issues. In spite of these concerns, educators believed that science should be integrated with other subjects, should be enjoyable and relevant, should develop positive attitudes and career awareness in male and female students, should include Canadian materials and local Saskatchewan materials, and should foster intelligent decision making.

Of the participants who responded, 86.6% indicated that they already include Saskatchewan examples in their science teaching. They felt that teaching materials relating to Saskatchewan should be generated by Saskatchewan Education (84.4%) or developed by teachers in the regions (77.4%). In order to effectively implement a science-technology-society-environment emphasis, teachers requested up-to-date information from government departments, business, and industry; data bank access; commercially-prepared materials; networking; and consultants. Without such support, science teaching will be reduced to the lowest common denominator--content teaching from textbooks by lectures. A designated core of science learning experiences and a rich variety of supplementary modules based on local and global issues appropriate to the developmental levels of students may help alleviate some of the legitimate concerns of educators.

In the breakdown of responses to the third recommendation by region, agreement was somewhat varied (from 71.9% in Region 6 to 97.0% in Region 8). Breakdown according to science teaching level and rural/urban location showed no distinct differences.

Science Curriculum Organization (Topic Four)

Elementary School Science (K-5)

Recommendation: **Science learning experiences should be provided for all elementary school children for at least the minimum time per week prescribed by Saskatchewan Education policy. The elementary science curriculum should be designed to provide for appropriate development in all the dimensions of scientific literacy. It should be part of an integrated, mutually-reinforcing elementary education program. Elementary science should be activity oriented and provide opportunities for children to actively explore and**

investigate their environment as a means of stimulating and nurturing their natural curiosity. Sound instructional materials must be readily available. The focus should be on fostering interest and developing the basic skills needed for students at this level to begin to develop an understanding of their world.

Most of the participants who reacted to this recommendation were elementary teachers; however, the responses of the other teachers and administrators were also included. Of 207 participants responding to this recommendation, 98.1% agreed.

Elementary school teachers indicated that science is an important component of the elementary school curriculum, but that they require help in delivering a program for which they have had little training or experience. Teachers expressed a need for assistance in providing an activity approach (63.4%), field experiences (46.0%), and mutual reinforcement with other subjects (41.1%). They expressed concern about availability of suitable curriculum materials and equipment, the time factor, and the burden of split grades.

Teachers at the elementary level indicated strong needs for the following curriculum guide components: scope and sequence charts (77.8%), teaching objectives (78.3%), lesson and unit/module planning guides (74.9% and 83.7%, respectively), teacher background information (79.3%), recommended references for teacher and students (70.4%), evaluation devices (70.9%), materials lists (71.4%), ideas for enrichment and reinforcement (77.2%), and Saskatchewan/Canadian examples (84.2%). Vocabulary lists (46.8%), bulletin board display suggestions (52.7%), safety guidelines (54.2%), and duplicating masters (52.7%) were selected less often as required curriculum guide components.

Elementary teachers provided many ideas for materials development and use of community resources to help teachers integrate science with other subject areas and include Saskatchewan and Canadian examples in their science programs. However, given time and local funding constraints, teachers looked to Saskatchewan Education for leadership in development and implementation of new science teaching materials for these purposes.

No regional, science teaching level, or rural/urban differences were noted in the statistical breakdown of the responses to the recommendation for elementary science curriculum organization. Elementary teachers and teachers from other levels who reacted to this recommendation were all highly in favor of it. Five regions reported 100% agreement (Regions 3, 4, 6, 7, and 8).

Middle Years Science (6-9)

Recommendation: **Science experiences for middle years students should be designed to contribute to development of all of the dimensions of scientific literacy. Science should continue to be activity oriented. Given the needs and learning styles of early adolescents, the activities should be personally and socially relevant. Middle years science should continue to develop basic life, earth, and physical science concepts begun in elementary school. However, it should emphasize science process skills that allow students to apply both skills and subject matter to personal situations and to societal and environmental issues that have a scientific and technological basis. Highly interesting and exciting activities should be developed for classroom, field, and community environments.**

Of the 172 participants who reacted to this recommendation, 95.3% agreed with it. Again, this sample included mostly middle years teachers, but other participants who were interested in this teaching level were also included.

Although teachers at the middle years level have varied educational backgrounds and range from secondary content specialists to general elementary science majors, certain basic concerns were expressed by the majority of these individuals. They were most concerned about the activity-oriented approach to science teaching (59.8%) and the personal and social relevancy of science to their students (66.3%). Less concern was expressed about science process skill development (41.0%) and field activities (41.6%). Analysis of written responses indicated that several other concerns should be addressed in the development of middle years science materials, including the application of science to decision making, the current lack of interest in science among students, the number of "unqualified" teachers that are required to teach science at this level, and subject integration. There were many teachers who were also concerned that the cognitive level of current middle years science textbooks is too high for many students.

The following components were most often indicated as being required in the science curriculum guide: scope and sequence charts (69.6%), teaching objectives (69.6%), lesson and unit/module planning guides (62.5% and 79.8%, respectively), teacher background information (69.6%), recommended teacher and student references (69.0%), evaluation devices (67.9%), materials lists (64.3%), provision for enrichment and reinforcement (73.2%), and Saskatchewan/Canadian examples (84.5%). As with the responses to the same question at the elementary level, components such as vocabulary lists (39.3%), bulletin board display suggestions (46.4%), safety guidelines (51.8%), and duplicating masters (48.8%) were seen as less important in the middle years guide.

Middle years teachers were also asked to respond to a question indicating their preference for curriculum organization at that level. The alternative organization patterns considered included the broad fields or disciplines-based science that is currently taught at this level in Saskatchewan, general science, integrated science, or an open choice. Of 154 teachers who responded to this question, 46.8% indicated a preference for an integrated science curriculum, 26.0% for broad fields, and 18.2% for general science. Explanation of what was meant by each of these organizational patterns was provided in Part B and was discussed in the introductory presentation at the meetings.

In response to questions about how to build into the middle years science curriculum Saskatchewan and Canadian examples and information about the scientific and technological contributions of various cultural groups and women, participants made many suggestions including development of special teaching modules, resource lists, audiovisual materials, and data banks. Teachers suggested that these materials could be developed by Saskatchewan Education, by teachers locally, and by government and industry. The idea of Saskatchewan-developed science textbooks was also suggested.

Breakdown of the reactions to the recommendation on middle years curriculum organization showed consistently high agreement by participants from all regions, from all science teaching levels, and from both rural and urban locations. Two regions (Regions 1 and 6) showed 100% agreement with the recommendation.

Secondary Science (10-12)

Recommendation: **In addition to general science in grade 10, two years of secondary science should be required for graduation. The existing discipline courses, such as biology, chemistry, and physics, should be modified to satisfy objectives in all of the dimensions of scientific literacy, including a science-technology-society-environment emphasis. A second science route should consist of two science-technology-society-environment courses (at the 20 and 30 levels). Both secondary science routes, or a combination of these two routes, should be acceptable for university entrance to first-year survey courses. Basic disciplinary survey courses as foundations for science specialization would be the responsibility of the university or technical school.**

This recommendation represents a departure from current practice at the secondary level. As a result, it was the most controversial component of the proposal for renewal of science in Saskatchewan schools. Based on the sample of 166 educators that responded to this recommendation, 63.3% agreed, 22.3% were undecided, and 13.2% disagreed. Regional breakdown of the results showed considerable variation in the regions from an extreme low of 33.3% agreement in

Region 1 (the next lowest agreement was 53.1% in Region 4) to a high of 78.9% agreement in Region 8. In the breakdown by science teaching level, participants teaching only secondary science indicated 51.3% agreement, and those teaching both middle years and secondary science indicated 64.1% agreement. Participants from other science teaching levels and combinations of teaching levels generally showed higher agreement with the recommendation. There was no definite difference shown due to rural/urban locations.

The degree of concern related to characteristics of the secondary science curriculum, such as problem-centered (36.3%), issues-oriented (47.1%), career awareness (33.8%), and controversial issues (49.4%), was not as high as that expressed by elementary or middle years teachers. However, in written responses secondary teachers expressed concern about the following: coverage of existing content material, the time factor, dilution of basic science content, integration and application of science to decision making, responsibility of student preparation for university or postsecondary training, preparation of students for existing departmental finals, suitability of textbooks, lack of current (relevant, practical, and local) materials, lack of student motivation, and community acceptance of alternative approaches.

Of the participants responding, 70%-75% expressed a need for lesson/unit planning guides, teaching objectives, evaluation devices, and recommended student and teacher references in secondary science course guides. In addition, the following written suggestions were given for improvement in secondary science teaching: greater emphasis on training and education of teachers, development of usable teachers' guides, inclusion of core and adaptive modules for teacher flexibility, inclusion of practical applications of science in technology and society, and ensuring that science is meaningful and interesting to students of varying cognitive abilities.

Secondary science teachers were also asked to indicate, within the science-technology-society-environment course option, which alternative organizational pattern they preferred. Of the 153 participants who responded, an integrated organizational pattern was preferred by 64.1%, general science was preferred by 18.3%, and 12.4% indicated "other," with answers typically relating to the existing discipline courses.

Secondary teachers gave similar suggestions to middle years teachers on how to build Saskatchewan and Canadian examples and the contributions of cultural groups and women in science and technology into secondary science courses. The need for leadership and coordination in this effort by Saskatchewan Education was strongly indicated.

Science Teaching (Topic Five)

Recommendation: **Science teachers should be prepared to use a variety of teaching strategies that are appropriate to the nature of the material to be learned and to the needs, capabilities, and interests of students. Science curricula should be comprehensive enough to accommodate various teacher capabilities, styles, and interests that are consistent with the goal of scientific literacy.**

This recommendation was agreed to by 97.6% of the 329 participants who reacted to it. Educators indicated that they are familiar with and have used a variety of teaching strategies. Most teachers (82.7%) indicated that they they are familiar with 8 to 13 of the listed teaching strategies. As well, the majority of teachers who responded (71.8%) have used between 5 and 9 of the strategies in their science teaching. However, they stated a preference and inferred in their students a preference for about 4 to 6 of the teaching strategies. Teachers typically indicated (75.1%) that, of the 13 strategies listed, only 1 to 3 were most effective for student development in science.

More than two-thirds of the participants (72.1%) indicated that inservice would be required for between one and five of the listed strategies. Responses indicated that inservice development should focus on simulations and role playing, case studies, laboratory investigations, values clarification, instructional modules, and learning centers. In general, educators indicated that curriculum materials need to be developed for most of the listed teaching strategies. Several teachers indicated their preference for the lecture method of teaching science.

In general, it appears that pressures of time and numbers of preparations, especially in smaller or rural schools, serve to reduce diversity in teaching methods in science. The typical lowest common denominator of lecture and textbook teaching discussed in the report of the Science Council of Canada (1984) appears to be all that many teachers can muster, given current working conditions.

Breakdown of the responses to this recommendation on the use of science teaching strategies showed no distinct differences among regions, science teaching levels, and rural/urban locations. Four regions (Regions 3, 4, 5, and 7) indicated 100% agreement with the recommendation. Urban teachers also reported 100% agreement.

Evaluation in Science (Topic Six)

Recommendation: **Student evaluation in science should measure the degree to which students are becoming scientifically literate. Teacher effectiveness in helping students achieve scien-**

tific literacy should also be addressed. Program evaluation should be an ongoing process. Information should be routinely gathered on students, teachers, and programs so that gradual shifts and adjustments can function to improve science education continuously so that larger adjustments are not necessary.

Of the 330 educators who reacted to this recommendation, 87.6% agreed, 10.9% were undecided, and 1.5% disagreed. It appeared, from responses to questions in this section, that teachers concentrate on student evaluation (96.0%), and that the focus on evaluation of teaching (42.2%) and program (46.5%) is lower. It appeared that, with appropriate support, teachers would be prepared to evaluate their teaching and programs in science. For example, 91.3% of the 323 participants responding indicated that they would not object to Saskatchewan Education conducting periodic learning assessments to determine program effectiveness and scientific literacy levels of the student population of Saskatchewan schools.

Student evaluation is accomplished primarily by content tests using multiple choice, short-answer, and long-answer questions (76.4%). Some teachers indicated using only multiple choice and short-answer question types (16.9%), and some reported using only long-answer questions (1.9%) in the testing of students. Participants indicated that the following additional evaluation devices are used to derive student grades: student observation/anecdotal records (56.5%), laboratory/experiment results (73.6%), and essays/research reports (70.5%). As well, teachers indicated that they also include student attitude, class participation, science fair projects, oral examinations, and field trip activities as part of their student evaluation in science.

Participants indicated that they would have more difficulty with evaluation of their teaching (35.3%) and evaluation of science programs (32.0%) than with student evaluation (22.2%). In evaluating students, teachers reported that they would require support in order to evaluate the following dimensions of scientific literacy: values that underlie science (71.5%), science-technology-society-environment interrelationships (54.5%), and science-related interests and attitudes (55.7%). Proportions of teachers requiring evaluation support for the other dimensions of scientific literacy were much lower (7.1%-21.7%). Teachers requested science evaluation support through science inservice (78.4%), science evaluation handbooks (69.3%), and evaluation sections in curriculum guides (61.4%). Provincial science assessments were seen as a less popular support option (28.6%).

Further breakdown of the responses to the recommendation for evaluation in science provided no definite distinctions among regions, science teaching levels, or rural/urban locations.

Support System for Science Teachers (Topic Seven)

Recommendation: **In order to meet objectives that develop scientific literacy in students, teachers should receive support from curriculum leaders in education at all levels of decision making. This support should take the form of high-quality curriculum guides and materials, appropriate science equipment and supplies, staff development experiences for teachers, and other specific teaching and learning aids.**

Responses from educators to questions about support for science teaching were clear and consistent. There was 99.4% agreement among educators reacting to this recommendation. In general, teachers want any kind of support they can get. Teachers indicated that they currently rely primarily on science curriculum materials (73.6%) that are in the school (including the textbook as curriculum guide) and audiovisual materials (87.3%) for support. Human resources (51.1%) are used less often. Although some city schools have well-equipped secondary science labs and some intermediate and elementary science rooms, rural teachers generally lack special facilities inside or outside the school. Given the pressures of time and inadequate funding, teachers use what is conveniently "within reach" and little else. However, teachers enrich the setting of their classrooms for science with bulletin board displays (85.1%), living plants and animals (63.1%), ongoing experiments (56.6%), aquaria (44.7%), and career corners (11.0%). Although 87.1% of those responding indicated that their school had a science budget, only 47.9% indicated that it was adequate to meet their needs.

More teachers appeared to want support in the forms of teaching materials and inservice/workshop opportunities than in the form of support people. Teachers indicated that appropriate curriculum materials (77.4%), teaching modules (79.8%), field and laboratory guides (73.1%), and audiovisual materials (81.7%) would be most helpful to them. Computer materials (65.1%) and science periodicals (65.7%) were also seen as helpful to science teachers. Textbooks (47.1%) and agency publications (35.2%) were seen as the least helpful materials for teachers in maintaining effective science programs.

More educators indicated a need for staff development through inservice and workshop opportunities (70.5% and 88.9%, respectively) than conference opportunities (47.1%) or university courses (29.8%). In the area of human resources support, participants indicated that science resource people from agencies and industry (57.8%), divisional science consultants (47.1%), and science teacher organizations (46.5%) would be of most help. School science representatives (31.0%), regional science coordinators (36.9%), and a Saskatchewan Education science advisor (32.3%) were perceived as less helpful to teachers in maintaining effective science programs. Although the above results might indicate otherwise, written responses consistently indicated a need for science consultants at various educational levels from Saskatchewan Education to regional and local levels.

Equipment storage space (88.3%), appropriate tables (77.0%), and access to running water (84.2%) were indicated as basic equipment needs. Safety equipment needs were expressed by 65.9% of participants. A refrigerator was seen by participants as somewhat less necessary for teaching science effectively (42.6%). There was a strong indication (92.7%) that teachers want an active teacher network (some included the term "clearinghouse" in written responses) to facilitate exchange of ideas, information, and materials for science teaching.

One of the most significant outcomes of this study was the expressed need for leadership in science education in Saskatchewan. Teachers expressed needs for well-developed core curriculum materials, the flexibility of adaptive (optional) modules, consultants to facilitate instructional change, resource materials, data banks to help keep science content current, and teacher networks.

Statistical breakdown of the reaction to the recommendation on the required support system for science teachers showed uniformly high agreement in all regions, for all science teaching levels, and for rural and urban locations. Six regions indicated 100% agreement with the recommendation (Regions 1, 2, 3, 4, 5, and 7). Urban teachers also reported 100% agreement.

Science-Related Societal Issues (Topic Eight)

Recommendation: **The science curriculum should provide students with opportunities to discuss science- and technology-related societal and environmental issues at a level appropriate to their ability to understand the issues.**

Most educators agree with this recommendation. Of 332 participants who responded, 93.7% agreed. In fact, many participants (86.0%) stated that they currently deal with science-technology-society-environment issues in their science teaching. Written responses indicated that a wide variety of issues, ranging from acid rain to nuclear power, are part of their present science courses. However, these educators also indicated that the issues were more likely to be part of a teacher-initiated discussion (90.6%), lecture (70.1%), or student-initiated discussion (67.8%) than the focus of group study (34.3%), simulations (19.9%), or active student participation in community issue resolution (14.8%).

Participants stated that curriculum units/modules (75.6%), resource lists of units/modules (64.2%), background information on issues (75.0%), inservice (67.1%), and special conferences or workshops (61.7%) would help them deal more effectively with science-technology-society-environment issues in the classroom.

Implied in this recommendation is a change in instructional approach from teacher as purveyor of knowledge (primarily through the lecture method) to

teacher as a facilitator or director of information access and interpretation and of debate concerning the scientific basis for decision making. Written responses from participants indicated that, although desirable, science-technology-society-environment issues will not likely become a legitimate part of the science curriculum in the absence of materials development and leadership in instructional development. The attitude for change in teachers' minds appears to be directly related to the kind of support they can anticipate.

Breakdown of the responses to the recommendation on science-related societal issues showed no distinct differences among regions, science teaching levels, and rural/urban locations. One region (Region 3) indicated 100% agreement.

Teacher Education (Topic Nine)

Recommendation: **Preservice education of all teachers of science should include university-level training in both physical and life sciences. This postsecondary education should be consistent with the goals of science education. Mechanisms should be established to reward teachers who maintain a high level of professional competence. Inservice courses or workshops should be established for all levels of science teaching and should be available at times convenient to science teachers. University funding should be adequate to ensure high-quality teacher education.**

Educators participating in the field study generally agreed with this recommendation. Of the 323 participants who responded, 85.1% agreed. Of the 4.3% who disagreed and 10.5% who were undecided, many of the comments, both written and verbal, indicated that there was concern about the teacher reward statement. In fact, the intention was not that a monetary differential be established, but that administrators take responsibility for encouraging excellence. Most teachers understood and accepted this; however, some were suspicious that merit ratings and merit pay were rearing their ugly heads once again.

Given the goal of scientific literacy, more of the 314 educators who responded considered their science background (48.1%) than their education background (29.3%) to be inadequate. Teachers understand this terminology because they generally distinguish between their professional education and their academic backgrounds. Participants indicated that inservice on teaching strategies would be most useful if focussed on the science-technology-society-environment (66.4%) and the interest and attitude dimensions (48.0%) of scientific literacy. The dimension of science processes ranked next (41.4%), followed by values that underlie science (39.6%). (These percentages and those that follow in this section represent cumulative percentages of responses in the top three ranks of a seven point ranking scale.)

The rankings for preference of university education courses were similar. However, ranking for unversity science courses were higher for science-technology-society-environment interrelationships (59.6%) and science processes (45.5%) than for science-related interests and attitudes (37.4%) and values that underlie science (32.7%). In all three questions, the nature of science, key science concepts, and scientific and technical skills ranked low.

In general, educators stated that science and science education backgrounds are important prerequisites to good science teaching at all levels. Because of rapid developments in science- and technology-related fields, teachers stressed the importance of continuous inservice and updating to ensure that they are teaching valid information or are equipped to help students access up-to-date information. High quality teacher education personnel and facilities are required to provide continuous staff development.

No distinct differences showed up when the responses to the recommendation on teacher education were broken down by region, science teaching level, and rural/urban location.

Relationship of Science Education to Common Essential Learnings (Topic Ten)

Recommendation: **Curriculum development in science education should include detailed level-by-level articulation between the goals of science education (the dimensions of scientific literacy) and the goals of education for Saskatchewan (the common essential learnings).**

Responses of the 321 participants who reacted to this recommendation were 91.0% in agreement. Educators indicated that, of the common essential learnings, personal and social value skills and technological literacy are being handled least adequately by present science programs. Each of these common essential learnings received an adequacy rating from educators of only 29.9%. About two-thirds of the participants felt that numerical and quantitative literacy is being handled adequately in their present science program (66.6%), and about one-half of the participants believed that communication skills, creative and critical thinking, and independent learning are being handled adequately in their present science program (57.9%, 45.0%, and 52.7%, respectively).

Participants indicated that personal and social value skills would be most difficult to achieve (59.0%) even through modified core science programs. This was followed by creative and critical thinking (43.7%). Other common essential learnings ranked considerably lower (15.6%-29.8%).

There were few written comments indicating anticipated problems related to the alignment of the goal of scientific literacy with the goals of education as translated into the common essential learnings.

No obvious differences appeared when the responses to this recommendation on common essential learning relationships were broken down by region, science teaching level, and rural/urban location.

Providing for Individual and Group Differences (Topic Eleven)

Recommendation: **Curriculum development in science education should make detailed provision for the special needs of all students regardless of gender, those with intellectual and physical disabilities, those who are gifted, and those who are culturally different. If possible, these provisions should be handled within the mainstream of science education.**

Of the 324 participants who reacted to this recommendation, 87.3% agreed with it. Although written and verbal comments received from educators generally agreed that curriculum materials must include provision for individual and group differences, there appeared to be some reluctance to assume responsibility for individual differences particularly because of the weight of current teaching responsibilities. Some teachers were concerned that only specially qualified individuals could provide help to certain kinds of students. Others were concerned that the time required to provide the proper amount of individual attention, particularly related to intellectual disabilities, would jeopardize the education of other students in classrooms.

Teachers simply felt unable to handle special needs related to intellectual disabilities (59.2%), physical disabilities (58.9%), cultural differences (53.4%), and the gifted (47.2%). They indicated a definite need to develop learning experiences in the science curriculum for students who have intellectual disabilities (75.8%), are gifted (71.4%), are culturally different (52.2%), and have physical disabilities (50.9%).

Written comments were often blunt and sometimes emotional. Teachers need help if mainstreaming is to be effective. Teachers want help with appropriate curriculum materials. Regional differences, cultural differences, intellectual differences--the diversity of student needs appears to be more than many already overworked teachers can bear. They want separate programs, inservice, and consultants. They are concerned about survival, indicating that one disabled student is equivalent to ten regular students. Regional differences must also be important considerations for curriculum developers, particularly the concerns of teachers in Northern Saskatchewan.

is equivalent to ten regular students. Regional differences must also be important considerations for curriculum developers, particularly the concerns of teachers in Northern Saskatchewan.

No differences were evident when the statistics on this recommendation were broken down by region, science teaching level, and rural/urban location.

DISCUSSION OF RESULTS

This study of science education involved educators in a process of deliberation about proposed directions for school science prior to policy development. The results, based on analysis of objectively scored answers to direct questions posed in a series of topics for discussion, were intended to reflect understanding of teacher and administrator viewpoints in response to proposals for renewal of the K-12 science curriculum. The results, based on analysis of written responses to open-ended questions, were intended to improve that understanding by probing for reasons for the views expressed in objectively scored response items.

It appears, from the results of the responses to major recommendations for renewal of science education, that the vast majority of educators agree with each of the proposals. In general, there appears to be a uniformly high degree of consensus among educators that all of the recommendations should be addressed by curriculum writers. However, one might question the ability of the Likert scale questions to capture the beliefs of educators with the precision needed to make important curriculum decisions. In order to reduce the risk of misunderstanding responses to objectively scored questions, the following cautionary statements are provided so that readers and curriculum developers have some understanding of the reasons for views expressed. These views were gleaned from written responses which probed teacher understanding of recommendations and general comments, both written and verbal, expressed at the 15 deliberative meetings held in all regions of the province.

Goals of Science Education

Scientific literacy as the goal of science education is difficult to criticize. It is universally endorsed by science educators as the legitimate goal of school science. For teachers to disagree with this goal would be like disagreeing with the virtues of motherhood or apple pie. However, according to Roberts (1983) and others, the concept of scientific literacy is subject to debate; definitions are numerous and variable.

In this study, scientific literacy was comprehensively defined as consisting of a number of interconnected dimensions (see Showalter, 1974). The description of the dimensions of scientific literacy presented to teachers is in the Appendix. Teachers were asked to read, discuss, and comment on a detailed conceptual framework for scientific literacy. They were encouraged to focus on specific dimensions with reference to such concerns as anticipated instruction difficulties, reasons for these difficulties, and support requirements to help alleviate such difficulties. It is possible that some teachers may not have understood the concept of scientific literacy as defined by these dimensions or that the implications were not clear, given the time they were given to reflect on these matters at the meetings. Written responses to questions did not appear to reveal such a problem, although many teachers were open and honest enough to indicate difficulty understanding one or more of the dimensions of scientific literacy and to indicate where they would require specific assistance to teach effectively toward such a dimension (e.g., values that underlie science, science-technology-society-environment interrelationships, and science-related interests and attitudes).

The meeting presentation prior to deliberation and response booklet completion attempted to clarify the concept of scientific literacy by reviewing each dimension and responding to questions. The presentation emphasis was on development of curriculum materials that would help teachers achieve a better balance of all of the dimensions of scientific literacy in their teaching. Educators who responded to questions on goals and objectives generally stated that they wanted curriculum materials to have goals clearly stated and activities designed to help students develop in each of the dimensions of scientific literacy.

Science Curriculum Framework

Although educators tended to agree with the concept of a K-12 framework for science education as an aid in achieving balance in teaching toward all of the dimensions of scientific literacy, they did indicate some concerns about particular proposals within the elements of this framework. The curriculum framework appears as Table 1 in this report. Questions in the topics for discussion probed for an articulation of these concerns. Teachers and administrators specified that their concerns were largely related to support that must be provided if new instructional strategies or a new program design were to be implemented. The participants did not appear to object to the idea of change but were skeptical about the means that would be in place to facilitate change.

Science Curriculum Emphasis

The concept of curriculum emphases was linked to the types of rationale that are either implicit or explicit in any particular teacher's classroom approach to science

(see Roberts, 1982). Teachers appeared to be somewhat unfamiliar with the concept of emphasis but appeared to understand the meaning intended after the presentation at the regional meetings. The inclusion of a science-technology-society-environment emphasis was intended as one component of a balanced approach to science teaching based on a variety of emphases (see Robert's, 1982, comments on "informed eclecticism"). Written and verbal expression of concern by participants related to support and leadership required for implementation.

Generally, teachers appear to accept a science-technology-society-environment emphasis as long as certain foundational and disciplinary program elements are ensured in the curriculum.

Science Curriculum Organization

Elementary teachers were asked to consider a broad fields approach to science program development. Intermediate level teachers were asked to consider a number of alternative approaches to program development. Reading material, in table form, and explanations of alternative organizational frameworks, such as general and integrated science, were provided. Some teachers appeared to have difficulty comprehending how alternative organizational patterns would function. Concrete examples of existing materials (mostly Canadian) appeared to facilitate consideration of alternative patterns of organization. There was a somewhat surprising amount of support for integrated science programs at the middle years level.

In written and verbal comments, secondary teachers generally supported retention of existing secondary science disciplines. However, a much larger number of these teachers than expected also responded favorably to the idea of an integrated science course or courses with a science-technology-society-environment emphasis forming a second route through high school science. Given the level of support, it would seem reasonable to begin development of an integrated science course at the grade 10 level and, perhaps, a second course at the grade 11 level. It appears that many secondary teachers believe that important science content would need to be "sacrificed" in order to add science-technology-society-environment material. Only through development and field trials with actual materials can it be demonstrated that core content, basic to problem-solving and decision-making process development, need not be sacrificed but rather reorganized in relation to issues that are meaningful to students. According to Roberts (1982), teachers who have been educated within one curriculum emphasis and who have been enculturated into a system based on respect for university undergraduate teaching methods (Medvitz & Watson, 1979) will naturally find it difficult to adapt readily to alternative conceptions of program design. The general willingness to consider alternative organizational frameworks expressed by the majority of secondary teachers in this study is encouraging.

Science Teaching

Recommendations within many of the proposals for renewal of science education either state or imply that change is necessary in school science teaching. They assume that teachers of science are positively predisposed to change if it can be demonstrated that valid arguments are directing that change.

This study attempted to determine if the assumption of positive predisposition to change was valid because, according to the Science Council of Canada (1984), the achievement of objectives for science education depends in large measure on the importance accorded those objectives by teachers. It was as obvious in this study as it was in the Science Council of Canada's national study that contextual factors, such as availability of appropriate curriculum resources, teacher background, student ability and interest, learning environments, operating conditions (such as number of preparations and timetable scheduling), and school and community support, influenced teachers' attitudes and predispositions to proposals for change. In fact, it would be naive to expect any real change in the balance of objectives in science education in the absence of information about these factors.

The results of this study demonstrate that arguments made by the Science Council of Canada (Orpwood & Alam, 1984) for a teacher support system that effectively addresses these contextual requirements as a way of removing barriers to instructional improvement apply to Saskatchewan. Educators in this province appear to agree that change is required--and in the direction proposed--but that unless these contextual barriers are addressed, little actual change can occur.

Evaluation in Science

This study attempted to elicit responses from educators on matters related to evaluation of students, teachers, and programs. The results were both encouraging and discouraging. Generally, teachers accept responsibility for student evaluation and use traditional kinds of tests of content. They appear to agree that scientific literacy is the appropriate goal of science education and accept this concept in multidimensional form. The concern that is expressed most often by teachers relates to their responsibility for evaluation of all of the dimensions of scientific literacy. Although many excellent evaluation devices currently exist or are being developed for this purpose, most teachers are unaware of this diversity and thus are skeptical about their ability to assess student development effectively. This uncertainty is understandable when teachers assume that they may be almost totally responsible for instrument development or access. Teachers genuinely want to know how they contribute to learning and attitude development, but they need assistance with new evaluation techniques.

Many teachers appear to be interested in receiving feedback about their teaching. Many high-quality resource materials exist. However, awareness and expertise are lacking. Research and development are obviously important to teachers, but leadership is required to reduce the anxiety often associated with self-evaluation or peer counselling.

Program evaluation, although acknowledged as important, appears to be beyond the capability of many teachers. Workload demands, as reported by teachers, leave little time for systematic examination of the consequences of teacher actions (see Stenhouse, 1975). It appears to be the case that "knowing what is good for you is not enough incentive to change." Basic survival forces teachers to set priorities, and program evaluation tends to be a little added frill.

Support for Science Teachers/Science-Related Societal Issues

The results of the study indicate that curriculum resources, professional leadership, and physical facilities are inadequate to allow desired objectives, existing or proposed, to be met. Teachers cannot be expected to teach in a vacuum and remain effective. Elementary teachers with minimal background in science and science education not only need effective curriculum materials, but also need high-quality inservice to facilitate implementation and continuous development. Intermediate and secondary teachers require no less. Science textbooks change every year or two because knowledge about science and about instruction is changing so rapidly. Computer data bases, laser disc technology, and compact disc interactive modes of communication and information access can play an important role in helping teachers in cities and remote areas to access up-to-date, relevant information. Information technology can also provide background data for student issue resolution and decision making.

The traditional teacher role as expert in a discipline or purveyor of knowledge is being rendered obsolete, and the complexity of local, regional, and global issues that require analytic and thinking skills are largely interdisciplinary. To assume that students can be functional as decision makers with respect to science- and technology-related societal and environmental problems with a content-rich but process-poor school background in science is hopelessly naive given our understanding of learning and transfer. Teachers must realize that a support system based on modern technology and an instructional plan based on information and analysis mean a change in teacher role that is crucial to development of personal and social competence in students who will be required to function as adult decision makers in the next century.

Leadership in development and implementation of this support system is pivotal in the survival of public education. A vision of the kind of education that students

will need in the future is required by key decision makers of the present (see Saskatchewan Education, 1985).

Teacher Education

A significant part of the crisis in science education described in current literature is directly related to the manner in which science is taught in schools. It is not surprising, then, that there are serious concerns expressed about the state of teacher education in North America and widespread demands for large-scale reform of teacher education (National Commission for Excellence in Teacher Education, 1985; Association of Teacher Educators, 1986; Carnegie Forum on Education and the Economy, 1986; Holmes Group, 1986).

Case studies of science teaching (Stake and Easley, 1978; Olson & Russell, 1984) found that, beyond elementary levels where relatively little science is taught or taught well, science teaching consists primarily of a lecture-textbook style of teaching. Medvitz and Watson (1979) present a logical rationale for such an approach based on the influence of affiliation of science teachers with scientists and the enculturation process that occurs as novice teachers are introduced to the status quo. In this study of science education in Saskatchewan, many teachers defend the predominantly lecture-textbook method as efficient and effective. In written responses, they describe alternative teaching strategies as unproductive and frivolous.

The Holmes Group (1986) describes one-way teaching, where subject matter is "presented," as simplistic and naive. Rather, the group subscribes to the notion of the fully competent professional teacher who understands that teaching and learning are interactive. Accordingly, teacher education includes academic and clinical learning that prepares one to manage both content mastery and the complex social relations of the classroom. It trains teachers to recognize that the social context in which learning occurs is a critical dimension over which they have considerable control and that multiple teaching strategies can create learning opportunities for young people who were deemed failures by others.

According to the Holmes Group, current literature demonstrates that well-meaning, well-educated persons will teach as they have been taught--by direct telling--unless teacher education programs provide practice in the more indirect but powerful teaching strategies like maieutic methods, role playing, and social interaction and cooperation strategies. The development of desirable professional dispositions in prospective teachers is as much of a challenge as the cultivation of valued attitudes in younger students. Didactic instruction is of limited value. Teachers cannot be disinterested, lethargic, and uncaring if they are to cultivate curiosity and excitement in their students.

In science education, current literature and research indicate that teachers need a judicious mixture of background and pedagogy. Scientific literacy as a goal of science teaching demands that teachers use a variety of teaching techniques. Lecture, demonstration, lab, and textbook are necessary but not sufficient for effective learning in all students. Teacher education, both preservice and inservice, must have the necessary resources to work with teachers to improve the quality of their instruction so that they are competent to address goals and objectives under all of the dimensions of scientific literacy.

Relationship of Science Education to Common Essential Learnings

Common essential learnings are translations of the broad goals of education into statements and descriptions that can be understood more clearly by teachers. Because these learnings are defined more precisely, they can be the subject of debate and deliberation by teachers and the general public. In turn, deeper understanding will eventually lead to greater accountability on the part of teachers for ensuring that these objectives are addressed in school, whatever the subject area.

In science education, a parallel kind of evolution toward teacher accountability is occurring with the specification of the dimensions of scientific literacy. Preciseness in definition facilitates the task of alignment of science education objectives with those of general education. Teachers in this province agree that science education should be more directly connected to the goals of general education through common essential learnings. However, they believe that this task requires expertise beyond their abilities and time beyond their capabilities. They are anticipating that the necessary leadership will provide curriculum materials and resources to help them do their job. They indicate commitment but lack the expertise; they have the predisposition but lack the time required to translate goals into objectives. Clearly, strong leadership is required.

Providing for Individual and Group Differences

Can teachers cope with the variety of students that is found in "average" classrooms? Educators in our study appear to be overburdened by their regular workload, and many are unwilling to accommodate wide differences in intellectual or physical functioning.

If teachers are to work effectively with female students, with culturally different students, and with disabled students, they obviously require preservice and inservice training. This does not mean one-shot lectures at conferences but effective staff development including coaching and follow-up experiences. If funding is not directed toward special classes and programs, it should be directed toward assist-

ing all teachers to cope with the diversity implied in mainstreaming, whether for gifted students, students with disabilities, or for minority groups students. Funding cannot be reduced through elimination of special programs. Given appropriate leadership, many excellent programs in science education could be introduced into regular classrooms.

It is obvious from the results of this study that teachers are skeptical about mainstreaming because they sincerely believe it may be harmful to regular students and because they do not feel competent to cope with the diversity of student types.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendatons are based on the results of a study of science education as they apply to Saskatchewan schools. The study consisted of the following components: a review of current thought and research in the field of science education, development of a K-12 framework for curriculum development in science, and a field study that sampled teacher reaction to the proposed framework and elicited information about their needs and wants. Analysis of the literature and research and of the field study results yielded the conclusions. Renewal of science education in Saskatchewan schools should be based on the following recommendations.

1. **The major goal of K-12 science education should be the development of scientific literacy.**

   Curriculum goals, aims, and objectives imply directions for education. They are influenced by factors such as epistemology, society/culture, learning theory, and learners. Science educators have determined that goals in science for the K-12 school system must be broadened to reflect a balance among all of the dimensions of scientific literacy. These dimensions are described in detail in Part B of the field study documentation and in the Appendix of this report.

   Curriculum committees will be selecting subject matter and learning experiences that effectively bring about the realization of goals, aims, and objectives. Selection criteria, whether implicit or explicit, typically include the following factors: significance (i.e., content or concepts based on the structure of a discipline); utility (i.e., the relevance of the curriculum to society); interest (i.e., the inherent meaning of material as related to learner experience); and human development (i.e., consideration of the intimate connection between individual capability and character). Curriculum committees should select science learning experiences based on a balance

among these criteria and a balance among the dimensions of scientific literacy.

2. **A K-12 science curriculum framework should be developed to organize the continuity and flow of core science learning experiences.**

   Science education should be based on a comprehensive, coherent, and consistent learning framework that can be used to guide planning and decision making at policy, curriculum design, and classroom instruction levels. The conceptual basis for this framework should be derived from the components of each of the dimensions of scientific literacy. The organizational basis should be derived from the program elements described in Table 1. Given the direction provided by this framework, curriculum development can proceed to define the detail required to permit teachers to provide appropriate science learning experiences at each grade level.

3. **Science curricula at all levels of K-12 education should include a science-technology-society-environment emphasis.**

   This does not mean that other possible curricular emphases, such as "solid foundation" and "structure of science," are not important and therefore should be ignored. It does mean that teacher awareness of the rationale for program presentation to students is important. It also means that balance among possible emphases, which include science-technology-society-environment, is prudent given the level of understanding about how children and adolescents learn science. Future citizens need to understand science subject matter as a basis for sound decision making. But subject matter by itself is not enough--students need practice in using subject matter and processes in their search for meaning and understanding of the natural physical world and the constructed technological world. It cannot be assumed that transfer occurs without practice.

4. **Science learning experiences should be provided for all elementary school children for at least the minimum time per week prescribed by Saskatchewan Education policy. The elementary science curriculum should be designed to provide for appropriate development in all of the dimensions of scientific literacy. Science should be part of an integrated, mutually-reinforcing elementary education program. It should be activity oriented and provide opportunities for children to actively explore and investigate their environment as a means of stimulating and nuturing their natural curiosity to better understand their world. Sound instructional materials must be readily available to elementary teachers.**

   Young children should be exposed continuously to science learning experiences designed to develop interest and intrigue in science as a way of knowing and as a way of solving problems. These experiences must be relevant and

meaningful within the child's context of society and environment. They must also be appropriate for the cognitive developmental level of children. When writing or selecting science curriculum materials, curriculum planners should be sensitive to these criteria and to the need for balance among all of the dimensions of scientific literacy. Elementary teachers should be accountable for the provision of science according to curriculum guidelines.

5. **Science learning experiences for middle years students should build on the development of all dimensions of scientific literacy that were initiated at the elementary level. Given what is known about the needs, interests, and learning styles of early adolescents, middle years science should be activity oriented and activities should be personally and socially relevant, especially in the contexts of local society, including culture and technology, and environment.**

   Middle years science should continue to develop basic concepts in life, earth, and physical sciences. This may be accomplished through the existing curriculum if it is revised to reflect a balance among all of the dimensions of scientific literacy. Some middle years teachers should have the opportunity, with an appropriate support system, to explore the potential of integrated middle years science programs. Continuous revision of these programs can be based on a variety of classroom experiences. However, any experimental program should satisfy the basic criteria of scientific literacy objectives, subject matter development, and systematic evaluation.

6. **Secondary science courses should be revised so that they form a logical extension of scientific literacy development begun at the elementary level and extended through the middle years level.**

   A core of basic disciplinary information in biological and physical sciences should form the basis for subject matter development at the secondary level. This core subject matter should be developed in a series of required units for biology, chemistry, and physics courses. A number of optional modules should be developed for these courses so that secondary science teachers can select from a variety of possibilities according to their teaching style, their students' needs and interests, and community or environmental opportunities.

   A second integrated program through secondary science should eventually exist. However, development of such a route should proceed cautiously and responsibly. The initial stage of this program should be the development of an exemplary science-technology-society-environment course for the grade 10 level. This course should be piloted and field tested under controlled conditions by enthusiastic teacher-developers. Wider participation could follow when teachers have had the opportunity to critically examine the course. Development of grade 11 and 12 courses might then proceed as teachers are

assured that basic subject matter need not be sacrificed when alternative instructional methods assume different teacher roles.

7. **Teachers of science should be prepared to use a variety of teaching strategies that are appropriate to the nature of the material to be learned and to the needs, capabilities, and interests of their students. Science curricula should be comprehensive enough to accommodate various teacher capabilities, styles, and interests that are consistent with the goal of scientific literacy.**

Strategies employed by teachers reflect their views of role and function, their understanding of the nature of science and of scientific literacy, and their level of professional commitment.If students are to be exposed to authentic science experiences, they require more than the mere possession of information. They should learn to access, interpret, and apply information as a basis for sound, rational decision making. This implies that teachers must do more than present information. They must learn to expand their role through discriminant use of a variety of teaching strategies such as case studies, simulations, community studies, field studies, individual and group inquiry, and issue-related problem solving and decision making. They must do this because broadening the concept of science teaching to reflect all dimensions of scientific literacy demands it, because a rapidly expanding body of research on relationships between instruction and learning demands it, and because case study evidence from exemplary programs in science demonstrates it. Children and most adolescents learn science more effectively by engaging in activity. Teachers should have access to curriculum materials that provide information about how to teach as well as what to teach. This, coupled with effective inservice that includes classroom coaching, should support teachers in their efforts to develop new teaching skills.

8. **Student evaluation in science should measure the degree to which students are becoming scientifically literate. Teacher effectiveness in helping students achieve scientific literacy should be assessed. Program evaluation should be an ongoing process. Research information should be gathered routinely on students, teachers, and programs so that gradual shifts and adjustments can function continuously to refine and improve science education, and the probability of larger, more traumatic changes can be reduced.**

Most examinations and tests in science measure only knowledge acquisition. Consequently, teachers treat other objectives as added frills, not valued by students or the public. Areas such as critical thinking, creativity, problem-solving skills, and science-technology-society-environment interactions are not currently assessed. Evaluation of student development in each of the dimensions of scientific literacy entails a broader conceptualization of what constitutes appropriate measuring devices. Many of these devices already exist or are undergoing development and validation. Lack of teacher aware-

ness of evaluation devices that assess scientific literacy should be rectified. Development of and access to these evaluation devices is critical to program implementation. Departmental examinations should be modified to assess all dimensions of scientific literacy. Teachers also need access to instruments designed to measure teaching and program effectiveness.

Saskatchewan Education leadership is required to assist teachers in accessing and effective using of new techniques of evaluation as a means of making more intelligent decisions about students, teachers, and programs in science.

9. **In order to meet objectives that develop scientific literacy in students, teachers should receive support from leaders at all of the levels of educational decision making. This support should take the form of high-quality curriculum materials and equipment, reasonable facilities, and inservice or staff development experiences for teachers.**

Teachers have professional responsibility for the growth and development of young people. The mental stress and physical effort required to provide effective, stimulating daily learning experiences for a wide diversity of students makes teaching a demanding profession. To ask science teachers to consider alternatives to familiar routines appears reasonable only when considered in the context of the support they perceive necessary to assist them with their professional growth and development. Science consultants are needed to assist curriculum committees and teachers in the renewal of science education in Saskatchewan. Curriculum guides and other up-to-date teaching materials for science must be developed or selected to accommodate widely differing teacher backgrounds and experience. Effective staff development programs in science are required on a continuing basis to ensure that the needs of teachers and students are addressed.

Specifically, Saskatchewan Education should have a full time science coordinator to oversee curriculum and materials development, inservice, networking, and ongoing research into questions surrounding program effectiveness. Regional curriculum coordinators should have some liaison, needs assessment, and local inservice coordination duties related to science teaching. Local school divisions and schools should designate science representatives to discuss implementation concerns and maintain materials and supplies. Teachers of science need regular opportunities to meet and exchange ideas and to engage in inservice and development related to science. Advanced technology, such as compact discs, laser discs, videotapes, and videodiscs, although expensive to initiate, can save millions of inservice dollars if developed intelligently. Access to data banks is necessary to help students and teachers to use current information. This can save money in the long run because science print materials, including textbooks, change every year or two.

10. **Teacher education programs in science should be consistent with the goals of science education, that is, should provide for teacher competence in each of the dimensions of scientific literacy.**

    This means that all teachers of science should have university courses in both physical and life sciences. Teachers of middle years and secondary levels should have additional science courses in physical and biological sciences, the nature of science, and the interaction of science with other ways of knowing in society (e.g., economics, political science, human ecology). This also means that all teachers of science should have university courses in education that provide methods of teaching science. These courses should focus on science curriculum and teaching strategies as they apply to meeting objectives within each of the dimensions of scientific literacy.

    Teacher education should be continuous throughout the career of the teacher. Inservice and staff development opportunities in science should be available on a regular basis. University faculties should be encouraged to contribute to inservice experiences for teachers.

    Provision of high quality science education materials, facilities, and human resources are prerequisite to high quality teacher education in science.

11. **Curriculum development in K-12 science education should include detailed level-by-level articulation between the goals of science education (the dimensions of scientific literacy) and the goals of education for Saskatchewan (the common essential learnings).**

    The movement in science education aimed at developing all of the dimensions of scientific literacy is consistent with and mutually reinforcing of the movement in education aimed at developing the common essential learnings. Scientific literacy implies that the focus in science must be broadened from content acquisition to development of problem-solving and decision-making skills centered around science-related societal issues. This involves development in communication skills, personal/social skills, independent learning skills, and creative- and critical-thinking skills that have not typically been associated with science courses. Numerical and technological literacy are central to a science-technology-society-environment approach to science.

12. **Curriculum development in K-12 science should make detailed provision for the special needs of all students regardless of gender, those with intellectual and physical disabilities, those who are gifted, and those who are culturally different.**

    If policy dictates that these provisions should be handled within the mainstream of science education, then teachers require curriculum materials and consultants as support. All learners can be successful in science if

resources and time permit the appropriate variation in type, quality, and quantity of instruction.

POSTSCRIPT: A STRATEGY FOR IMPLEMENTATION

1. Saskatchewan Education should employ a provincial science coordinator within the Curriculum Development Division.
2. The provincial science coordinator should meet with the existing Science Curriculum Advisory Committee, which has recently overseen the field study of science education in Saskatchewan, for discussion of direction. Study results and a statement of direction for science education in Saskatchewan have been prepared for this committee by Dr. E.P. Hart, University of Regina (June, 1987).
3. The provincial science coordinator should work with the Science Curriculum Advisory Committee in seconding a science curriculum developer/writer to begin curriculum selection and development based on Advisory Committee guidelines.

    a) The seconded curriculum developer/writer should be a secondary teacher with excellent writing ability who understands curriculum development principles and the meaning of scientific literacy and who has an exemplary teaching record.

    b) The secondment should be for a limited period (e.g., one year) for the specific purpose of developing a science-technology-science-environment course for the grade 10 level.

4. The provincial science coordinator should work with the Science Curriculum Advisory Committee to develop a process for selecting/developing an elementary science program.

    a) This program could be based initially on one or more exemplary commercial programs supplemented with Saskatchewan-based modules. Some variation among programs would be desirable.

    b) The key to implementation will be teacher access to inservice on demand.

5. The provincial science coordinator should develop a research program to monitor the effectiveness of the elementary science program(s).
6. The provincial science coordinator should work with the Science Curriculum Advisory Committee to conduct trial experiments with selected teachers on offering alternative middle years science programs. Alternatives should be

evaluated through a planned program of research. Curriculum revision should then occur, focussed on objectives related to each of the dimensions of scientific literacy.

7. The provincial science coordinator should work with the Science Curriculum Advisory Committee to establish a variety of secondary science alternatives within existing disciplines. A research program should monitor the effects of alternatives and curriculum revision should begin. The goal is that all disciplines should move toward a balanced approach to all dimensions of scientific literacy.

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APPENDIX

Dimensions of Scientific Literacy*

The proposed basis for the K–12 science framework for Saskatchewan schools is the set of goals defined as the dimensions of scientific literacy. The following description of the fine structure of scientific literacy in observable terms was derived from 15 years of literature research that attempted to determine common factors in the goals of science education. Each factor in each dimension can be regarded as a continuum along which each student progresses. The dimensions of scientific literacy in this description also provide criteria for evaluation in science, which should be the basis for curriculum development. The list of scientific literacy factors is followed by Table 2 which suggests the grade levels at which the factors should be built into the curriculum.

Nature of Science

The scientifically literate person understands the nature of science and scientific knowledge.

Science is both public and private. Authentic science experiences should introduce students to the private and intuitive aspects of scientific inquiry and discovery as well as to the more formal public aspects of science.

The nature of scientific knowledge is such that it is:

1. tentative. It is subject to change and therefore does not purport to be truth in an absolute and final sense. This characteristic does not diminish the value of the knowledge in the eyes of the scientifically literate person.
2. public. It is based on evidence that is public as opposed to personal. It assumes that other individuals would arrive at similar conclusions when confronted with the same evidence.
3. replicable. It is based on evidence which, at least in theory, could be obtained by other investigators working in a different place and at a different time given similar conditions.
4. probabilistic. It enables probabilistic, as opposed to absolute, predictions and explanations when applied to real situations.
5. human related. It is a product of humankind resulting from an effort to impose order on nature or find patterns in nature and involves creative imagination. The knowledge itself is shaped by and from concepts that are a product of culture.
6. historic. Scientific knowledge of the past has provided the basis for today's knowledge, which in turn will provide the basis for tomorrow's knowledge. Past science knowledge should be viewed in its historical context and not be degraded on the basis of present knowledge.
7. unique. Scientific knowledge is one of several ways of knowing that man has developed. It is distinguished from other ways of knowing by virtue of the nature of its knowledge and its procedures for generating new knowledge. Conflict may

*From Science for Saskatchewan Schools: Proposed Directions. Field Study. Part B. Framework for Curriculum Development (p. 6-13) by Saskatchewan Education, 1987.

occur when the same thing or event is explained by science and some other way of knowing.

8. holistic. Scientific knowledge produced by the various specialized sciences contributes to an overall conceptual scheme which is internally consistent. The differences among the specialized sciences are differences of degree rather than of kind.
9. empirical. Scientific knowledge is based ultimately on and/or derived from observation or experiment even though theory may be a useful guide to further work. It has its origin in the real world and is dependent on sense experience.

Key Science Concepts

The scientifically literate person understands and accurately applies appropriate science concepts, principles, laws, and theories in interacting with society and the environment.

The key concepts of science are:

1. cause-effect. It is a relationship of events that substantiates the belief that nature is not capricious. Once established, it enables predictions to be made.
2. change. Everything is in the process of becoming different or something else. The rate at which it happens varies from very fast to very slow so that it may be unnoticed in these extreme cases. It may involve several stages or mechanisms.
3. cycle. Certain events or conditions seem to be repeated at regular intervals or periods.
4. energy-matter. It is interchangeable manifestations of substance and that which enables something to be moved or changed.
5. entropy. Entropy is an expression of the randomness, disorder, or chaos in a collection of things. It always increases in a closed system.
6. equilibrium. It is that state of affairs in which changes or tendencies to change occur in opposite directions, exist, or happen at equal rates or are of the same magnitude.
7. evolution. Evolution is a series of slow changes that can be used to explain how something got to be the way it is or what it might become in the future. It is generally regarded as going from simple to complex.
8. field. It is a region or space in which something influences or affects something else, often without direct physical contact.
9. force. It is a push or a pull.
10. fundamental entities. Fundamental entities are those units which are useful in explaining certain phenomena. They are units of structure and function.
11. gradient. It is a situation in which the intensity of something varies in a more or less regular pattern.
12. interaction. It is a situation in which two or more things influence or affect each other.
13. invariance. It is a characteristic of an object or a situation which stays constant even though other characteristics may change.

14. model. It is a more or less tentative scheme or structure which seems to correspond to a real structure, event, or class of events and which has explanatory value.

15. orderliness. Orderliness is the belief that there is either order in nature or that man is able to impose order on nature. It includes the various schemes or patterns that are used to express this order such as the periodic table of elements.

16. organism. An organism is an open dynamic system which is characterized by the processes of life. It may be used as an analog to explain certain non-life events or things.

17. perception. It is the interaction between the human mind and the external world.

18. probability. It is the relative certainty, or lack of it, that can be assigned to certain events happening in a specified time interval or sequence of other events.

19. population. It is a group of fundamental entities that have certain similarities or common characteristics.

20. quantification. It is an expression containing a numerical component resulting from measurement and associated with a concrete or abstract attribute of a thing, situation, or event.

21. replication. Replication is a belief that doing the same things will produce the same results if all other conditions are the same. It is a necessary characteristic of scientific experiments.

22. resonance. It is an action within one system which causes a similar action within another system.

23. scale. It is a consideration that other characteristics of or relationships within a system may or may not stay the same as its dimensions are increased or decreased.

24. significance. It is the belief that certain differences which exist or which follow certain actions exceed those that would be expected to be caused by chance alone.

25. symmetry. It is the belief that most, if not all, patterns in nature are structurally or functionally independent of direction.

26. system. It is a group of things or events which can be defined, at least in part, by boundaries that one person can communicate to another and which enable it to be discussed and studied more effectively.

27. theory. It is a connected and internally consistent group of sentences, equations, models, or a combination of these which serves to explain a relatively large and diverse group of things and events.

28. time-space. It is a dimension of the real world which separates things and events.

29. validation. It is a belief that similar relationships obtained by two or more different methods reflect an accurate representation of the situation being investigated.

Processes of Science

The scientifically literate person uses processes of science in solving problems, making decisions, and furthering understanding of society and the environment.

Some processes or thinking skills are more complex or integrated and include more basic processes. Intellectual skills are acquired and practiced throughout life so that eventually some control over these processes can facilitate learning. This control or strategy acquisition can provide information-processing and problem-solving abilities that go beyond any subject matter curriculum. Process skills such as accessing and processing information, applying knowledge of scientific principles to the analysis of issues, identifying value positions and reaching consensus through evaluation strategies are believed to include the more basic processes of science.

The basic processes of science are:

1. classifying. It is a systematic procedure used by a person to impose order on collections of objects or events.
2. communicating. It is any one of several procedures involving various media and which carries information from one person to another.
3. controlling variables. It is identifying and managing the factors that may influence a situation or event so that the effect of a given factor may be learned.
4. defining operationally. It is producing definitions of a thing or event in terms that give a physical description and/or that which results from conducting a given procedure.
5. designing experiments. It is planning a series of data-gathering operations which will provide a basis for testing a hypothesis or answering a question.
6. formulating models. It is devising a mechanism, scheme, or structure which will act or perform as if it were a specific real object or event.
7. hypothesizing. It is stating a tentative generalization that may be used to explain a relatively large number of events but which is subject to immediate or eventual testing by one or more experiments.
8. inferring. It is explaining an observation in terms of previous experience.
9. interpreting data. Interpreting data is finding a pattern or other meaning inherent in a collection of data. It leads to stating a generalization.
10. measuring. It is a procedure by which one uses an instrument to estimate a quantitative value associated with some characteristic of an object or an event.
11. observing. It is the most basic process of science in which a person's senses are used to obtain information about the environment.
12. predicting. It is predicting what future observations will be on the basis of previous information, which distinguishes it from guessing.
13. questioning. It is to raise an uncertainty, doubt, or unsettled issue which may be based on the perception of a discrepancy between what is observed and what is known by the questioner.
14. using numbers. It is the technique of using number systems to express ideas, observations, or relationships, often as a complement to the use of words.
15. using space-time relationships. It is the description of spatial relationships and their change with time.

Values That Underlie Science

The scientifically literate person interacts with the various aspects of society and the environment in a way that is consistent with the values that underlie science.

The values that underlie science are:

1. longing to know and understand. It is a conviction that knowledge is desirable and that inquiry directed toward its generation is a worthy investment of time and other resources.
2. questioning. It is a belief that questioning is important. Questions are generally prized although some are of greater value than others because they lead to further understanding through scientific inquiry.
3. search for data and their meaning. It is prizing the acquisition and ordering of data because they are the basis for theories which, in turn, are worthwhile because they can be used to explain many things and events. In some cases these data have immediate practical applications of value to mankind, as in cases in which data enables one to assess accurately the severity of a problem in society and/or the effects of policies directed to improve such situations.
4. demand for verification. It is a high regard for requests that supporting data be made public and that new empirical tests be invented and/or conducted to assess the validity or accuracy of a finding or assertion.
5. respect for logic. It is an esteem for those chains of inference that lead from raw data to conclusion according to some logical scheme and an insistence that conclusions or actions not based on such chains be subject to doubt.
6. consideration of premises. It is a prizing of frequent review of the basic external and internal assumptions from which a line of inquiry has arisen, especially when they are used as a basis for determining further action.
7. consideration of consequence. It is a belief that frequent and thoughtful review of both the direct and indirect effects resulting from pursuing a given line of inquiry or action is worthwhile and that a decision to continue or abort the inquiry or action will be made in terms of the consequences.

Science-Technology-Society-Environment Interrelationships

The scientifically literate person understands and appreciates the joint enterprise of science and technology and the interrelationships of these with each other and with other aspects of society and the environment.

Some of the factors involved in the interrelationships among science, technology, and other aspects of society are:

1. science and technology. There is a distinction between science and technology, although they often overlap and each depends on the other for continued progress. Science deals with generating and ordering conceptual knowledge. Technology deals with design and development, the application of scientific or technological knowledge often in response to social and human needs.

2. variable positions. Scientific thought and knowledge can be used to support different positions in response to specific problems such as population control or water fluoridation. Thus, it is normal for scientists and technologists to disagree among themselves, even though they may invoke the same scientific theories and data.

3. social influence on science and technology. The selection of problems investigated by scientific and technological research is influenced by the needs, interests, and financial support of the larger society.

4. ultimate value of science knowledge. Although scientists often pursue what, on the surface, seem to be socially irrelevant phenomena or investigate apparently trivial phenomena, history shows a significant proportion of these studies eventually have broad application value in various and sometimes unexpected technologies. A viable bank of scientific knowledge is required to ensure the future success of technology.

5. impact of science and technology. Scientific and technological developments have real and direct effects on each person's life. Not all effects are desirable, nor are any effects completely free of some undesirable side effects. In essence, there seems to be a trade-off principle working in which each gain is matched by one or more losses in terms of what has been. The trade-off principle involves items of knowledge, belief, and social structure as well as those of a material nature.

6. science requires openness. Science thrives best when there is a free flow of questions, ideas, and results that is not restricted by personal boundaries or external authority.

7. technology controlled by society. Although science requires freedom to inquire if it is to function fully, applications of scientific knowledge and of technological products and practices are ultimately determined by the whole of society including scientists and technologists. These groups have a special responsibility to inform the public and other decision makers of both the possible consequences of such applications and the need to search for such consequences.

8. public understanding gap. A considerable gap between scientific and technological knowledge and public understanding of it has existed in the past, continues to exist in the present, and will exist in the future. Constant effort is required by scientists, technologists, educators, and the public to minimize this gap.

9. resources for science and technology. The conduct of modern science and technology requires considerable resources in the form of talent, time, and money. Many of these resources, such as that of talent, require long-term preparation and allocation.

10. limitations of science and technology. Science and technology cannot guarantee a solution to any specific problem. In fact, ultimate solution of any problem is usually impossible, and a partial or temporary solution is all that is ever possible at a given point in time. Solutions to problems cannot be legislated, bought, or guaranteed by extreme allocation of resources. Some problems and areas of human concern are not amenable to the approaches of science and technology.

11. scientists and technologists are human. Scientists and technologists are people. In fact, outside of their special field, they may not exhibit strong development of all or even most of the dimensions of scientific literacy. All people, not just an elite few, are capable of doing science and technology at their own level of

sophistication. By the same token, vocations in some aspect of science and technology are open to practically all people.

12. science, technology, and natural resources. Society has the ability and responsibility through science and technology to regulate environmental quality and the usage rate of natural resources to ensure a good quality of life for this and succeeding generations.
13. science, technology, and other realms. Although there are distinctive characteristics of the knowledge and processes that characterize science and technology, there are many connections to and overlaps with the other realms of human knowledge and understanding.

Science-Related Interests and Attitudes

The scientifically literate person has developed a richer, more satisfying, and more exciting view of society and the environment as a result of science education and continues to extend this education throughout life.

The following factors contribute to this dimension of scientific literacy:

1. interest. The individual feels and expresses a satisfactory level of interest in science. At the very least, the person does not hate science.
2. confidence. The individual believes that a measure of self-satisfaction will be attained by participating in the doing of science and in understanding scientific things.
3. media preference. The individual chooses to become involved (reading, watching, and visiting) in a significantly high proportion of science-related television programs, newspaper articles, books, and public displays.
4. explanation preference. The individual shows a significant preference for the scientific explanation of a given event or thing compared to nonscientific explanations for the same event or thing, assuming that the scientific explanation is at an appropriate level of sophistication.
5. avocation. The individual pursues, has pursued, or would like to pursue a science-related hobby such as shell collecting, photography, or bird watching.
6. vocation. The individual either is considering entering a science-related job or career or has seriously considered entering such a field.
7. continuous learner. The individual, no matter what age, has gained some scientific knowledge within the very recent past. Frequently, some line of scientific inquiry is willingly pursued by the individual. This may take the form of enrolling in a science course which is not required by any formal program of study to which the person is committed.
8. response preference. The person gives a high proportion of science-based responses when questioned about events and things in an informal situation. This is especially significant when the questioner is not a teacher or other authority figure.
9. hero perception. The person has a relatively high esteem for the roles of the scientist and technologist in today's world and acknowledges several specific scientists and technologists as having made significant contributions in the past.

Scientific and Technical Skills

The scientifically literate person has developed numerous manipulative skills associated with science and technology.

The list of skills that follows represents manipulative skills important to the achievement of scientific literacy:

1. measuring distance. The individual accurately measures distance with appropriate instruments (e.g., meter stick).
2. measuring mass. The individual accurately measures mass with appropriate instruments (e.g., balance).
3. measuring time. The individual accurately measures time with appropriate instruments (e.g., watch).
4. measuring volume. The individual accurately measures volume with appropriate instruments (e.g., graduated cylinder).
5. measuring temperature. The individual accurately measures temperature with appropriate instruments (e.g., thermometer).
6. using electronic instruments. The individual can use electronic instruments that measure physical or chemical characteristics or biological functions (e.g., ammeter, oscilloscope, pH meter, camera).
7. conversion ability. The individual accurately conducts simple conversions among the variables listed above (e.g., $density = \frac{mass}{volume}$).
8. computer interaction. The individual can load *canned* computer programs and interact with them.
9. using magnifying instruments. The individual effectively uses optical magnifying instruments (e.g., microscope, telescope, binoculars).
10. using natural environments. The individual effectively uses natural environments in appropriately sensitive ways (e.g., collecting, examining, and reintroducing specimens).
11. manipulative ability. The individual demonstrates the ability to manipulate material objects (e.g., assembling simple equipment following the manufacturer's instructions).
12. using equipment safely. The individual demonstrates safe use of scientific and technological equipment in the laboratory, field, and everyday experiences (e.g., Bunsen burner or alcohol lamp, electrical equipment, chemicals).
13. using audiovisual aids. The individual independently uses audiovisual aids in gathering information.